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A young badger at the entrance to a set. Photograph by Arthur Brook. (See "Badgers in Britain".)

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DISCOVERY

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The Progress of Science

What is Vernalisation?

WHAT'S VERNALISATION? This question is one that is posed with monotonous regularity, the asking of the question being usually a reflex action prompted by the reading of a piece of Soviet propaganda claiming that another million acres or so have been planted with vernalised cereal seed. A full answer entails a careful study of the results of many years of research into plant physiology. Readers who want a fairly full summary of the relevant investigations and of the somewhat inconclusive deductions drawn from them will find it provided in a new book from the Chronica Botanica stable; this is entitled *Vernalisation and Photoperiodism*, and consists of a symposium of articles by fifteen authors headed by A. E. Murneek and R. O. Whyte.

The technique of vernalisation is, of course, very old indeed. *Natural* vernalisation has benefited mankind for hundreds of years; for vernalisation occurs naturally with every crop of winter cereal which is stimulated into early flowering as a result of the freezing of the seed in cold weather. The occurrence of vernalisation was recognised a long time ago; in 1857 J. H. Klippart of Ohio recorded the following observation:

> To convert winter into spring wheat, nothing more is necessary than that the winter wheat should be allowed to germinate slightly in the fall of winter, but kept from vegetation by a low temperature or freezing, until it can be sown in the spring. This is usually done by soaking and sprouting the seed, and freezing it while in this state and keeping it frozen until the season for spring sowing has arrived. Only two things seem requisite, *germination* and *freezing*. . . . The experiment of converting winter wheat into spring wheat has met with great success. It retains many of its primitive winter wheat qualities, and produces at the rate of 28 bushels per acre.

Early references to vernalisation can be traced back still further, in fact twenty years before Klippart.

But sixty years were to elapse before scientists were able to make any substantial addition to our knowledge of vernalisation. Starting from a belief that winter cereals must pass through a period of low temperature before they will shoot and flower, the German worker Gassner began experiments on vernalisation towards the end of the first World War. In 1918 he published the results of his initial investigations in which he used the variety of rye known as *Petkus*, which has ever since been the fashionable material for vernalisation research all over the world. These results led Gassner to the following conclusion:

> *The spring and winter forms of Petkus rye differ in that spring rye is practically independent of any need to pass through a cold period before it can achieve shooting; winter rye, on the other hand, will not flower unless it passes through a cold period either during germination or at some stage after germination. For winter rye low temperature is a condition for the 'release of flower formation'.*

The famous Russian physiologist Maximov followed up Gassner's experiments, working with seedlings. As the American monograph on vernalisation quoted above states, the vernalisation technique "was still applicable chiefly to laboratory trials and crop cultivation in greenhouses, owing to the fact that the treatment was applied to seedlings, which could not be handled on a bulk basis like seeds".

Lysenko, a protégé of Vavilov in the heyday of Russian botanical research, took the subject further with his researches on the effect of temperature on the development of cereals and cotton; his earliest results, obtained while he was at the Experiment Station at Ganja in Azerbaidzan, were published in 1928. He claimed that the various distinctive stages in the growth of cereals—such as seedling emergence, the emergence of the ears and flowering—are completed more rapidly at higher temperatures than at lower. (Such phenomena have, of course, long been familiar to people who run hothouses.) But in spring cereals, *and more especially in winter forms*, the phase of shooting does not always show this relation. A winter cereal, for example, can be prevented from flowering by too high a temperature. By 1929 Lysenko was able to present to the All-Union Congress of Genetics, Selection, Seed Production and Animal Production a whole 'creed' of vernalisation. A major point in the 'creed' was that winter cereals will perform satisfactorily if slightly sprouted or soaked grain was chilled at about 3°C. for a definite period; for the variety of wheat he used, called *Kooperatorka*, the period was thirty-eight days; for winter barley, twenty-eight days.

In 1931 and 1932 Lysenko published instructions for the treatment of seed by what he called '*jarovizacija*' (in Russian literature the term 'yarovisation' is commoner than

the synonymous term 'vernalisation'). Behind this simple technique lay an imposing edifice of theory, involving the principle of phasic development as it is called, a principle which many researchers have, however, found to be more confusing than useful.

What of vernalisation in practice? Lysenko's activities led to Russian farmers being taught how to vernalise their grain in barns, this being a relatively simple affair because the Russian winter gave them the low temperatures required. According to Russian statistics, vernalisation has been widely used; in 1932, 43 thousand acres were sown with vernalised seeds; the figure for 1937 is given as 10 million. The Chronica Botanica monograph remarks that "more recent data have not been seen; it is not known to what extent, if at all, Russian farmers are now using the method, or whether any centres for treatment and distribution of vernalised seeds have been operating".

Quite apart from any possible application in farming, the technique holds great interest for the plant physiologist, and it is true to say that the great body of research done in this field is interesting mainly for the ideas it throws into the common pool of physiological theory. Prof. F. G. Gregory and his woman assistant, Dr. O. N. Purvis, of the Imperial College of Science and Technology, South Kensington, have probably contributed more to our understanding of vernalisation than any other workers.

Out of their results emerged the conclusion that vernalisation involves all of the following factors:

(1) the embryo in the seed and its biochemical constituents;
(2) the source of organic carbon available;
(3) the source of nitrogen and the mineral salts;
(4) the effect of low temperature;
(5) the effect of length of day.*

The Gregory-Purvis explanation of vernalisation involves the postulated existence of a flower-forming hormone or *florigen*. During vernalisation a substance that changes into the florigen (what is called a *precursor* of the florigen) is supposed to accumulate in the embryo within the seed. This substance is mobilised and accumulates in all growing points of the rye shoot; when a certain critical concentration is reached then flowers start to form. It is supposed that during vernalisation the concentration of florigen (or its precursor) increases so that the critical level is reached the sooner; seeds that have been vernalised are supposed to be richer in the florigen and therefore give rise to plants which flower earlier. A genetic factor is also involved; heredity gives a spring rye greater abundance of florigen than a winter rye. All five of the factors listed above affect production of the florigen in one way or another.

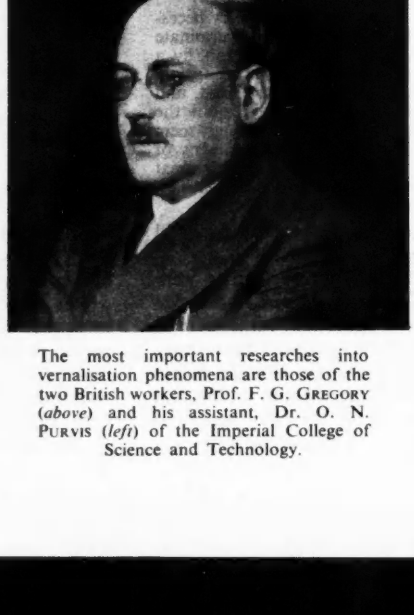
So far all attempts to isolate the florigen have failed, but researches on conditions of flowering are now beginning to link up with researches into plant hormones (the interested reader should consult K. V. Thimann's book, *The Physiology and Chemistry of Hormones*, Chapter 3; New York, Academic Press, 1948). The stage is now set for a major advance; as Thimann of Harvard says in his foreword to this very useful monograph on vernalisation "the state of the field is such that a single clear-cut result might change its whole aspect overnight".

Finally, it is worth recording that practical results of economic importance to producers of bulbs, such as tulips and hyacinths, are being derived from the vernalisation experiments carried out in Holland. Details of these are given in this monograph.

Underwater Explosions: The Bubble Effect

THE BUBBLE EFFECT (Fig. 1), which accounts for the tremendous damage that can be done by submarine explosions, was the subject of a recent note in "Progress of Science" (DISCOVERY, September 1948, p. 272). That note was based on the account given in *Science at War* by J. G. Crowther and Prof. R. Whiddington.

That account tended to give maximum credit to British workers, in particular Sir Geoffrey Taylor, for discovering



The most important researches into vernalisation phenomena are those of the two British workers, Prof. F. G. GREGORY (*above*) and his assistant, Dr. O. N. PURVIS (*left*) of the Imperial College of Science and Technology.

* Here the reader really needs to consult a book on plant physiology for further details about photoperiodism, the term used for the response of plants to the length of daily exposure to light. It needs to be appreciated that in some plants—known as *long-day plants*—flowering is brought on more quickly if the plant is exposed to a long daily exposure to light (usually more than 14 hours), or the plants must be exposed to light for a *minimum* time each day if they are to flower; in *short-day plants* usually 10 hours exposure to light, or less, brings on flowering. Examples of long-day plants are: spring varieties of cereals, spinach, lettuce, radish and potato. A good example of a short-day plant is chrysanthemum. Plants which are 'neutral' include tomato, dandelion, buckwheat and cotton—in these so-called 'neutrals', flowering is brought on by 10 to 18 hours of light—they even flower under continuous illumination.

the bubble effect. A truer appreciation of the investigations done into this effect is provided in Robert H. Cole's book, *Underwater Explosions* (Princeton University Press, 1948; Geoffrey Cumberlege, London; pp. 437, 42*s*.), which makes it abundantly clear that credit for the investigations leading to an understanding of the bubble effect must be shared among a great many researchers, working on both sides of the Atlantic.

The author himself worked on problems of submarine explosions at the Underwater Explosives Research Laboratory, a war-time organisation established under contracts of the Woods Hole Oceanographic Institution with the Office of Scientific Research and Development (OSRD), and later with the U.S. Navy's Bureau of Ordnance. This American outfit corresponded to the 'Undex Works' of the British Navy at Rosyth.

On the American side scientists like H. A. Bethe studied underwater explosions. Bethe, for example, formulated in 1942 an important theory of shock waves (published in OSRD Report 545). Names associated with the British investigations include Sir Geoffrey Taylor, W. G. Penney and S. Butterworth. The latter is well known for his researches at the Admiralty Research Laboratory; Taylor and Penney need no introduction to most of our readers, as their work on the explosive force of the atom bomb has received wide publicity.

The sequence of events occurring when an explosive charge is detonated under water is very clearly described—in words, pictures and mathematical formulae—in *Underwater Explosions*. Fig. 2 is a key diagram from the book. It illustrates very neatly the principal feature of 'the bubble effect', which Crowther and Whiddington have described in the following words:

> The shock-wave from an underwater explosion is the same, whether the charge explodes above or below the ship. Why, then, should the effects in the two cases be different? The explanation rests on the fact that when the charge explodes in the water it forms an extremely hot bubble of gas, which expands at a tremendous rate. Consequently, the water is pushed away and acquires a high momentum. It continues to move outwards after the gas has expanded to the degree at which it is in equilibrium with the pressure in the water before the explosion. Thus the gas bubble expands beyond its equilibrium position and presently begins to recede again. The water walls of the bubble now begin to move inwards and rush towards each other with enormous speed compressing the approximately spherical bubble of gas back again into a small bubble. Then there is a sudden reversal, and the bubble once more begins to expand a second time with explosive violence. A second shock wave is then sent out. It is not so strong as the first, but when suitably placed, is able to do much damage. It was subsequently found that this explanation was also inherent in some mathematical calculations on underwater explosions made many years before the war by Butterworth, then serving at the Admiralty Research Laboratory, who showed that an underwater explosion under suitable conditions is not a single 'bang', as might be imagined, but a rapid succession of 'bangs' of diminishing intensity.
>
> The bubble is really an oscillating system, whose movement is relatively slow at the stage of full expansion and very fast at the stage of maximum contraction. Three or more expansions and contractions may occur, sending out three or more shock-waves, in decreasing order of strength.
>
> Consider, now, what happens when a charge explodes above a submarine. The bubble proceeds through its oscillatory expansions and contractions, but it also rises through the water, since it is a gas and lighter than water. The second and third shock-waves will occur farther and farther away besides being weaker and weaker. Thus they will do no harm.
>
> But what would happen if the charge exploded underneath the submarine? The bubble would rise, and the second and third shocks from expansion might be much nearer, or actually on the hull. In that case, though the shocks were intrinsically weaker, they would be in a position to do much more damage.
>
> A second effect also emphasises this tendency. The oscillating bubble of gas moving in water tends to be sucked towards any nearby rigid body. This is due to the same cause as the fall in pressure which occurs underneath a ship passing through a shallow channel, or when two ships sail very close to each other; it is a characteristic of the movement of fluids. Hence a bubble from a charge which explodes in the water near the side of a ship tends to move towards the side, or, if it is near the bottom, towards the bottom. Thus this effect, also, tends to bring the bubble nearer the submarine or ship, and to enable the secondary and tertiary expansions to exert their destructive effect.

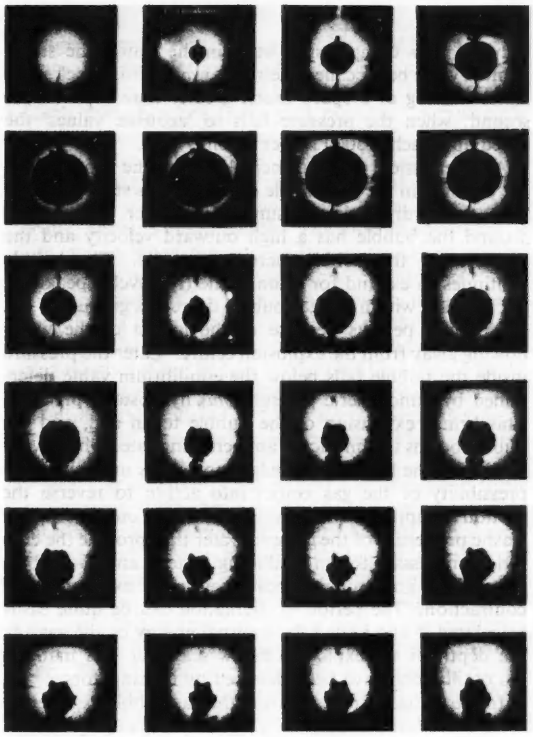


FIG. 1.—THE BUBBLE EFFECT.—This series of photographs demonstrates the way in which the gas bubble from the explosion oscillates. 15 grains of an explosive were detonated (*second photograph top line*); the initial increase in size of the gas bubble is seen, and also the ensuing decrease. The interval between the photograph is 1/250 second. (*From "Science at War", by Crowther and Whiddington.*)

Cole gives some figures which bring home to us the tremendous explosive force involved in an underwater explosion. He refers to an initial pressure of over 2 million pounds per square inch set up in an explosion of TNT. This pressure is relieved by the formation of an intense pressure wave and the terrific motion of the surrounding water away from the explosion centre. The explosion produces initially an extremely dense mass of gas; this gas bubble then expands, its pressure therefore diminishes and the pressure in the surrounding water also falls off rapidly. The pressure rise is followed by 'decay' of pressure, the events occurring in a very short time, measurable in milliseconds.

Once initiated the disturbance is propagated radially

outward as a compression wave in the water, the steep-fronted wave being called the *shock wave*. This shock wave starts moving at a speed much greater than 5000 ft. per second; when the pressure falls to 'acoustic values' the speed approaches 5000 ft. per second.

After emission of the principal part of the shock wave, the pressure in the gas bubble drops but it is still far higher than the hydrostatic pressure. The water immediately around the bubble has a high outward velocity and the diameter of the bubble increases rapidly. The bubble continues to expand for a long time (relatively speaking), the pressure within the gas bubble decreases gradually, but the motion persists because of the inertia of the water flowing away from the explosion centre. Later the pressure inside the bubble falls below the equilibrium value determined by atmospheric pressure *plus* hydrostatic pressure. This brings expansion of the bubble to an end, and the bubble begins to contract at an increasing rate. The inward motion of the bubble's boundary continues until the compressibility of the gas comes into action to reverse the motion abruptly. The inertia of the water coupled with the elastic properties of the gas and water thus provide the conditions necessary for an oscillating system, and the bubble proceeds to go through repeated cycles of expansion and contraction. The period of oscillation can be quite easily calculated if one knows the internal energy of the gas and the depth of the explosion below sea level. As many as ten oscillations have been detected by investigators.

In the course of its oscillation the gas bubble experiences a repulsive force away from a free surface, and is attracted towards a rigid boundary. *The bubble's motion is thus affected by its buoyancy and by the proximity of the surface of the water, and the sea bed or other surfaces such as ship sides.* Consequently it is no easy matter to calculate exactly how the bubble will behave.

What happens if the explosion occurs in shallow water may be quite complicated. On the theory explained above one expects the following phenomena to be visible at the surface:

1. A rounded dome of whitish water forms directly above the charge. Farther from the charge the surface is less disturbed, but a ring of apparently darkened water (known as the *slick*) spreads outwards for hundreds of feet; the extent of it indicates how far the shock wave has travelled.
2. If the bubble is near enough to the surface in an early phase of its motion (the gas pressure is then high), it can disturb the surface before it finally breaks through. The breakthrough which occurs later shoots up plumes of spray which may rise hundreds of feet.

The greater the depth at which the explosion occurs, the less pronounced are all these effects. Thus a charge of 300 pounds detonated at 400–500 ft. gives a visible 'slick', but the dome is insignificant and no plumes are visible even at much smaller depths.

Cole's monograph on underwater explosions is intended mainly for extreme specialists, but it is deserving of a quite wide readership because of the unexpected phenomena that have been revealed.

An important practical deduction from the miscellaneous results of the British and American researches (which were freely interchanged during the war) is that the effect of underwater explosions can be reduced by substituting yielding sides for over-rigid ship sides. With a yielding side the suction effect is minimised and the bubble would not be attracted towards the ship.

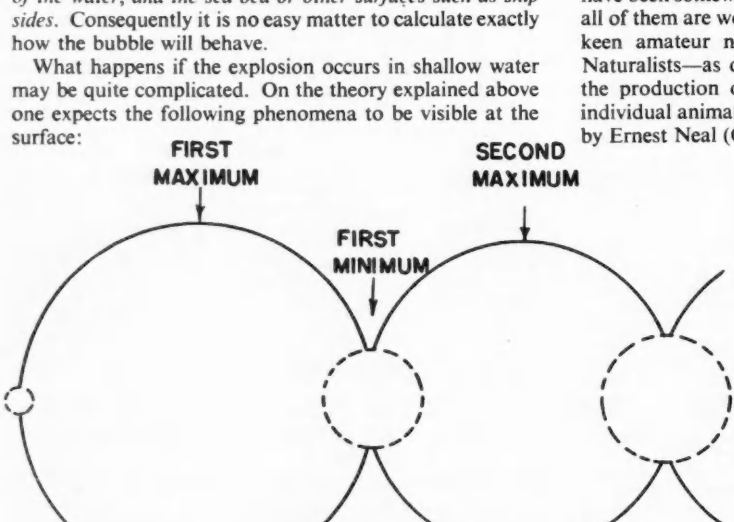


FIG. 2.—This diagram shows how the gas bubble from a submarine explosion pulsates. The gas bubble can expand and contract a number of times; more than ten oscillations have been detected in favourable cases. (*From Cole's "Underwater Explosions".*)

Badgers in Britain

ONE has had to qualify one's recommendation of the New Naturalist books as a series because some of the volume have been somewhat hard-going for the uninitiated, though all of them are worth a place in the library of a biologist or keen amateur naturalist. A new venture of the New Naturalists—as one may call the *editors* of the series—is the production of a series of monographs dealing with individual animal species. The first of these is *The Badger* by Ernest Neal (Collins, London, 1948; pp. 158, 12*s.* 6*d.*), and other monographs already announced will be devoted to detailed studies of the Redstart, Wren and Yellow Wagtail.

The badger book we recommend unreservedly and without any qualification to every reader who is interested in animals. It is beautifully written and illustrated, and its comprehensiveness and the high proportion of original, first-hand observations it contains put it straight into the same category as David Lack's monograph on the robin which has become a classic since its publication only a few years ago.

Neal's book is especially welcome as the British literature is so lacking in information about the badger. As the author himself says, "Ignorance about the badger is . . . appalling. Few people have even seen one alive though they may have lived in a district where they are common." For ourselves this is certainly all too true. For example, we

know of a badger set on Wimbledon Common where we have found the distinctive hairs which betray the animal's presence as certainly as does its spoor, but we have never seen the badgers themselves there. The nocturnal habits of the badger are, of course, the reason for the naturalist's neglect of this species; most animals which work 'burglars' hours' tend to be neglected.

The badger is by no means a rare British animal. It is widely distributed, and Neal considers it probable that there are badgers in every mainland county of Britain with the possible exception of Middlesex.

They are very common in Cornwall and Devon; in the former county they sometimes take advantage of the old mine-workings for their sets. There are plenty of badgers also in Cheshire, the Delamere Forest region, Cumberland, Westmorland, parts of Yorkshire (e.g. between Scarborough and York, and the region N.E. of Scarborough), Northumberland and Durham. It is common throughout Wales, except Caernarvon. The badger is not a native of Anglesey, but it is found there in Plâs Newydd Park; according to H. E. Forrest, writing in 1907, "It is supposed that badgers got there originally by crossing over the Menai Bridge by night." Notable is the badger's absense from the Isle of Man.

The badger cannot be described as common in Scotland, though there are few large areas where it is unrepresented.

The sections of the book dealing with the badger's habits are particularly good, as one would expect since Neal is the greatest British authority on badgers. Neal is a schoolmaster, and he has used his position to good effect, enlisting the aid of a number of senior biology students while he was at Rendcomb College to solve some of the more tricky problems of badger behaviour. His system was to post one student near each set, and rely on him to keep a complete record of everything that happened and when. In this way it was possible to build up a very detailed picture of one particular badger community.

Badgers are omnivorous animals, and in spite of the fact that the species belongs to the Carnivora there are times when the vegetable portion of its diet exceeds the amount of flesh eaten. The badger has very varied tastes; it will eat rabbits (young or old), rats, mice, voles and hedgehogs. On very rare occasions it eats lambs; some naturalists acquit the badger of the crime of lamb-killing, claiming that it only eats lambs that have already been killed by foxes. Probably Mortimer Batten is near the truth when he writes, "Badgers are not lamb killers, though individuals, if they have found dead lambs lying about, may attack, living ones; if so, they kill by biting behind the shoulder and leave it where killed." Badgers are partial to birds and birds' eggs though Neal says that badgers only eat adult birds when very hungry; they sometimes attack poultry, but Neal is convinced that the majority never do this. They like frogs and occasionally eat toads, snakes and lizards. Slugs are commonly eaten, snails only occasionally. Badgers are also insectivorous, and large numbers of insect skeletons are to be found in badgers' droppings. Those most commonly taken, according to Neal, are beetles, caterpillars, bees and wasps. The badger's partiality for beetles makes Brock a useful ally of man; for example Neal quotes from Dr. Colin Matheson this event which occurred during a plague of cockchafer grubs in Monmouthshire: "an entomologist friend who was investigating the problem noticed that the badgers were coming down at night and feeding on the grubs, no doubt getting rid of large numbers."

Vegetable items in the badger's diet include acorns, beech nuts, bluebell bulbs and pig nuts; occasionally it devours blackberries, apples and corn.

The badger is equipped with stink glands, which are found in many members of the badger family, or Mustelids, which also includes the pine marten, otter, mink, polecat, skunk, weasel, stoat and sable. The stink glands are brought into action when the animal is frightened, or otherwise excited—as can occur during play for instance. Neal considers that this is a defence mechanism, though he adds that, from a functional point of view, it may even be vestigial, now that the badger has so few natural enemies. A near relative of the badger is found in the larger islands of the East Indies and the Philippines, and is called the teledu (*Mydaus*); this definitely uses its musk glands as a defence and for that reason is known as the Stinking Badger or Stinkard.

Neal's description of the badger's underground fortress is very good. When 'sapping' the badger has no exact plan, but there does seem to be a very general one which is modified according to individual inclination and soil conditions. "Some of the main entrances always lead back a yard or so to a large chamber," writes Neal. "Its floor is hardened and smoothed by the feet of generations of badgers. It may be quite spacious and two or more feet high. This probably represents the first breeding chamber long ago when the set was first dug out. From this various tunnels radiate, and these lead to other chambers used as sleeping places or for breeding. It is astonishing how much bedding may be found in some of these. More tunnels lead out of these in a big set and probably go on doing so for a long way. In some soils which are deep and where the sets are dug into hillsides there may be tunnels at different levels. I know of at least one in Somerset where there are certainly three storeys. The tunnels go a tremendous way on occasions. . . . The breeding chambers are often situated in specially well-protected places; a common spot chosen is under the roots of a tree or some large stone or boulder. The badgers will then remove some of the earth from above the roots or stone, and on this platform one of the adults will lie with its face towards the entrance. It is thus in an almost impregnable position and can drop on any intruder. A variation of this method is for a step to be constructed in the tunnel just below the breeding chamber, so that anything entering is below the badger and would have to leap up the step. An added advantage of this type of construction would probably be good drainage."

Brock is a fairly tolerant creature, and other animals, such as rabbits, foxes and rats may be found living alongside badgers. Rabbits make good use of the soft earth which the badgers throw out at intervals, and make side tunnels of smaller diameter down which a badger could not follow. Neal records that foxes are common inmates of badgers' sets; in large sets a vixen may cub at the same time as, but in a different part from, a badger family. Fox lodgers are however liable to be evicted by the badgers on occasions.

Neal's final chapter is devoted to the subject of photographing badgers; here he has followed in the footsteps of Mr. Arthur Brook, a number of whose perfect photographs (including the one on our cover) grace Mr. Neal's book.

Science and the Prepared Mind

G. LAPAGE, M.D., M.Sc., F.Z.S.

In July last, at the Annual Meeting of the British Medical Association, Sir Henry Dale gave a lecture entitled "Accident and Opportunism in Medical Research", in the course of which he discussed the view that these two factors have played a definite, and sometimes an apparently decisive, part in the genesis of some advances in medicine, physiology and the other sciences allied to them. Without claiming for these two factors a greater influence than they have had, Sir Henry confined his remarks to accidental circumstances which have operated at, or shortly before, the birth of discoveries and did not consider those other accidental circumstances, which have operated at a point farther back in the life histories of discoverers. These earlier accidents of race, health, social and financial conditions, education and so on, have certainly had considerable influence upon discovery, for it is not too much to say that some of them have determined whether a man or woman shall become a scientist at all. The chance entry of a boy brought up in the atmosphere of the arts into a laboratory wherein he discovers a marvellous world unknown to his parents, the gift to him of a 'chemistry set' or a constructional toy, or, in later life, after he is well set in his course towards scientific distinction, a chance meeting with a leading scientist who happens to be sympathetic to him and also in a position to further, by practical help, his ambitions—all these are examples of a group of accidental circumstances which have led to great discoveries.

But accident and opportunism, influential though they have been, can be only the immediately exciting causes of discovery. They require, if they are to play any part in discovery at all, a mind pregnant with the practical combination of knowledge and experience which is capable of giving birth to the discovery. This mind, however great its store of facts and however wide its experience, must be, at the time when the exciting cause impinges upon it, directed towards the discovery that is made, sensitised to it, if the language of the immunologist may be used, and in a state of tension, expectation, search for the fact, or group of facts, which will resolve for it the chaos of data, conjecture, hypothesis and collateral evidence which awaits, like the heap of iron particles in the familiar demonstration of magnetic forces, the one influence which can marshal them into an ordered pattern. Given all this, the problem may be swiftly, perhaps instantaneously, solved.

The question whether the influence which initiates the performance of this remarkable mental trick is an accidental circumstance, the phenomenon which we call luck, or anything else, is not the question which we are here discussing. The important point for us is that it cannot act without the mind that is suitably *prepared* to respond to it; important, also, is the condition that this prepared mind shall be, at the moment of time when the exciting cause acts upon it, ready to respond by releasing the knowledge and experience that is necessary for the birth of the discovery.

An analysis of the methods by which some, though not by any means all, important discoveries have been made would show that their origin involved the exciting cause and the mind prepared to respond to it, which have just been described; in this article I can refer to two discoveries only, both of which are nowadays well known.

The first is the familiar discovery by Newton that the force of gravity holds the moon in its course around the earth. Escaping from Cambridge to Woolsthorpe to avoid the plague, Newton, whose mind was at the time intent upon this problem, saw, in the Woolsthorpe garden, an apple fall from a tree, it is said, and, although he must have seen this commonplace event innumerable times before, he experienced, on this particular occasion, a correlation of it with the problem that was, we may be sure, permeating, however little he realised it, his whole life at that time. He saw the apple fall; and his eager intuitive faculty, like lightning leaping from a cloud to a tree, flashed from the known phenomenon to the unknown and the problem was suddenly solved. There followed, no doubt, a great sense of relief, an easing of the tension of the mind straining after discovery, a rearrangement of its knowledge and experience; and, after that, a cold, calm period of labour during which the consequences of the discovery were thoroughly worked out.

The parallel between the method of this discovery and that of the discovery of penicillin by Sir Alexander Fleming is interesting. While Fleming was working as a member of a team studying variation among micro-organisms belonging to the genus *Staphylococcus*, he had to expose to the air the agar plates upon which these organisms were growing so that they could be examined with the low magnification of a dissecting microscope. He was not therefore surprised when he found that one of the agar plates had been accidentally contaminated with a fungus. This was an event which is just as commonplace as the fall of the apple seen by Newton, although it is biologically different from it. Most bacteriologists would deal with it by discarding the contaminated plate. Certainly if they were working upon a particular problem, as Fleming was, they would normally do this. Why, then, did Fleming not discard his fungal contamination? The answer must be that his mind, trained by Sir Almroth Wright, had been for most of his life interested in the destruction of bacteria by leucocytes, in the action of antiseptics and kindred problems, and was sensitised to these problems. For this reason, and, it can be suggested, for this reason alone, he noticed that around the area of the fungal contamination the growth of the *Staphylococci* had been inhibited.

That was the point—the zone of inhibited bacterial growth around the fungus. Here was a circumstance which was, to a mind always alert, as Fleming's was, for evidence of new kinds of bacterial inhibitions, all-important. It could so easily have been missed. No doubt it had been missed, as Fleming himself has suggested, by other bacteriologists. Possibly Fleming, too, had missed it on previous occasions. But on this occasion, notwithstanding

the fact that he was studying the variation of *Staphylococci*, he saw the possible significance of the zone of inhibited growth around the fungal contamination; and, obeying the bent of his mind towards bacterial inhibitions, he picked off and cultivated the contaminating fungus and presently made the basic discovery out of which Sir Howard Florey and Dr. Chain, and the Americans Dubois and Waksman and several others in the United States and various countries, have since woven, and are still weaving, our knowledge of antibiotics.

These two instances of what may be called the intuitive method of scientific discovery remind us quite remarkably of the methods of the poetic mind. The necessity for wide knowledge and experience, the awareness of hidden significance in it, the 'Sturm und Drang', (which is by no means absent from the scientific discoverer's mind), the period of unhappy, restless brooding, the intuitive eagle forever circling above the stormy sea of experience; and then, suddenly, for no apparent reason, out of the humdrum variety of common or garden experience comes the exciting cause. It may be, for the poet, a lady's smile or petticoat, a scene glimpsed upon Westminster Bridge, a dark vignette of the murk and misery of an industrial wilderness; for the scientist it may be the fall of an apple, a knock-kneed child in a Paris tram, or a mould-spore dropping on to an agar plate. But, whatever it may be, its powers are tremendous. It strikes from the mind immortal gold; but why it does, perhaps we shall never know.

This analogy drawn between the processes of the poet's mind and the scientist's will probably be contested. It will not be liked by those scientists who vigorously deny the view that many poets no longer work with words, but live, instead, in laboratories and, turning their eyes from the human soul, look outward into that world wherein beauty, sought with the mind rather than with the heart, glides into the shape and habiliments of truth. However little we like this view, it has to be conceded that the sense of beauty has played its part in the genesis of some discoveries.

Some mathematicians, especially, have said that their sense of beauty has guided their selection of the materials of their thought. They have, that is to say, used only conceptions that are beautiful and some of them have gone so far as to say that beauty has, in this way, led them to discoveries. Beauty, therefore, must be included in the list of exciting causes; and to some minds it has been the supreme influence which has directed the searching eye of their intuition. The truth, such a mind might say, is and must be beautiful; and only the beautiful, for such a mind, can light to flame that preparedness of the mind without which discovery cannot come.

The question whether the exciting cause or the prepared mind is the more important is a difficult one to discuss. One might as well debate whether sunlight or water is the more important to the life of our world. But certain it is that both are required. The history of science is full of the ghosts of discoveries which never, for lack of one or other of these two factors, come to birth. Some of these ghosts were glimpsed by men who lacked the knowledge and experience to give them life. Other minds, packed with the requisite knowledge and experience, never had the eye for the integrating detail; yet others no doubt experienced the exciting cause but could not make the intuitive leap from the commonplace to the immortal. Or it may be that what was needed was the ability to correlate phenomena occurring in different fields of enquiry, or just something quite unromantic and ordinary, such as a little more force of concentration on the problem, or nothing more than freedom from the domestic, financial and other cares of this world, which can so effectively break up, as a gardener's boots will break up gossamer, the delicate tissue of thought upon which both intuition and sensitisation of the prepared mind depend.

All these and other factors, such as the health of the discoverer at the time when he makes a discovery, the important circumstance that he may be, when the exciting cause works its magic in him, in poor rather than in vigorous health, or occupied, not with his problem, but with something different, and often with something quite absurdly ordinary, such as shaving, having a bath, or climbing a hill or taking a quiet walk or doing something which promotes a gentle increase of the circulation of his blood—all these factors play their part in discovery, but they cannot be discussed here.

A word, nevertheless, must be given to those tragedies of unaccomplished discovery indicated above. Any one of them could well provide material for another "Lear". For science within her laboratories they cannot exist; she has no concern with the souls of the men who suffered because they failed. She takes their legacies of unfulfilled desire and gratefully sifts them for materials which succeeding generations, better equipped by advances in every scientific field, add to the preparation of their minds. Then one day, to some suitably gifted man, the appropriate exciting cause appears; and suddenly, like the forefathers he has read about, he, too, leaps straight to his goal. One more discovery has been made; and one more ghost, once longingly glimpsed by a long-forgotten soul called Smith or Brown, has leapt at a bound to full and abundant life.

To these harbingers of discovery these Smiths who glimpsed the shadows only of truths which always, so to speak, hid from them round the corner, a great debt is due. Let it not be forgotten nor go unpaid. For their fault, never their own, was simply that they lacked that little more of endowment, that extra resolving power of the lens, which makes all the difference in the ever-changing, ever-expanding world of science, between success and failure. The significant correlations, the affinities underlying external differences, the hidden threads which, if the right combination of them is shaken, bring order out of chaos and fertile hypothesis where before there were only disconnected facts, these are the kinds of material out of which discovery is made. If a man, patiently labouring with hope of discovery in his heart, do nothing more than provide, for the mind of genius, that basis of preparedness to which its intuitions, as if through the corner of its eye, may at some magical moment bring the spark which lights an immortal flame, that is a job worth any man's whole life; and the genius, if he be a scientist, will be among the first to acknowledge the debt which he owes.

LAST MONTH we published a short biographical study of Einstein in celebration of his seventieth birthday, which fell on March 14. This month Dr. Lilley gives an appreciation of Einstein's Theory.

The Commonsense of Relativity

S. LILLEY, Ph.D.

Nature, and Nature's laws, lay hid in night:
God said, 'Let Newton be!' and all was light.
ALEXANDER POPE.

It did not last: The Devil howling 'Ho!
Let Einstein be!' restored the status quo.
J. C. SQUIRE.

WITH all respect to the poets, the impression created by these lines is, to put it mildly, distorted. They are based on the idea that Newton's laws of motion and gravitation are rather obvious statements about the behaviour of bodies, that they are no more than 'commonsense'. And since Newton explained a large part of the phenomena of nature in terms of these 'commonsense' laws, it is alleged that as a consequence of Newton's existence, all in the physical world was light.

But 'commonsense' is merely that view of the world which we have got used to, or been taught at our mother's knee or our elementary school. To Newton's contemporaries (or most of them) Newton was not talking commonsense. He had derived a good working explanation of the universe, and so the scientifically minded accepted his theory as true. But it was based on what seemed to be wildly improbable assumptions. *A body will continue to move in a straight line at constant speed unless it is acted on by a force!* But a force means a push exerted on one body by another. When a stone is thrown in the air, it is not being pushed by anything, and yet it moves in a curve and with varying speed. So this statement seems absurd. To make it plausible Newton adds: *any two material bodies attract one another by a force, called gravity, which acts at a distance!* A force acting at a distance is a very different thing from the push on which our intuitive notion of force is based. It is very far from 'commonsense'. After a generation or so, most men managed to convince themselves that action at a distance was a reasonable and comfortable idea. But even at the height of Newtonian success many doubted if it were really possible or conceivable. And at the beginning it was to the majority an extravagant hypothesis whose only justification was that it did enable one to predict the mechanical behaviour of things with some accuracy.

In the seventeenth century something on more Aristotelian lines would seem to be on the whole more in keeping with 'commonsense'. A body, when it is not being actively pushed, moves in the way that is natural to it. A stone falls to earth because that is the natural thing for it to do. If you want to prevent it from behaving naturally, you must exert a force on it, for example by putting a table underneath it.

The only trouble was that this Aristotelian outlook did not give an effective means of, say, calculating where the planet Mars will be on next New Year's Day, whereas the Newtonian laws did. So, improbable as they might seem, Newton's statements had to be accepted as the only basis for an effective science of mechanics and celestial mechanics. Even if they seemed to be unbelievable, Newton's laws had to be asserted again and again in the course of research or in the routine of teaching. And eventually men got used to them and came to regard them as intuitively obvious, as 'commonsense'. Then, and only then, could an epigrammatist believe that Newton had made the universe seem simple.

When Mr. Squire wrote his witty if somewhat inaccurate addition to Pope's couplet, the generality of men stood in relation to Einstein's theories in much the same relation as that between the ordinary man and Newton in, say, 1695. Einstein had made a number of assertions about the basic principles of the physical universe. The assertions conflicted with 'commonsense'—that is, they conflicted with the mixture of Newtonian and pre-Newtonian notions which all of us had come to regard as obvious. Unfortunately Einstein's theory had to be accepted, because deductions based on it corresponded much better with observed facts than did deductions from Newton's theory. So the situation was that Einstein's theory had to be accepted and yet it appeared to contradict 'commonsense'. Small wonder, then, that Mr. Squire felt that Einstein had plunged nature and nature's laws back into the night, and ascribed his creation to the Devil.

Since then 'commonsense' has begun to change—as it always does—and to accommodate itself to science. The process is far from complete. There can be very few people, if any, who think naturally or intuitively in terms of a curved universe whose geometrical properties have taken the place of gravitation. But we have begun to move in that direction. The Einsteinian universe does not seem as inconceivable as it did. Nor does the Newtonian universe seem so intuitively obvious.

Another common misconception, to which these epigrams excusably subscribe, is that both Newton's and Einstein's cosmological revolutions were the work of these two alone (or of the respective acts of creation by God and the Devil). Newton expressly denied this view in his famous remark about standing on the shoulders of the giants; and we can be sure that Einstein would do the same. In each case, other workers prepared the way; others were struggling towards the new conceptions that Newton or Einstein put forward. And the role of the great genius in each case was not to create a new theory of the world out of nothing, but rather to synthesise the work of his predecessors and put it in a new light which revealed its full significance.

Newton's mechanics as such was perfectly consistent with a principle of relativity—namely the principle that it is not possible to detect the absolute velocity of an object, but only its velocity relative to some other object. Newton realised this point, but he chose nevertheless to believe in an absolute space and therefore in the possibility of

measuring absolute velocity. His belief was based on theological considerations. But the notion of absolute space passed with the rest of Newton's theory to the eighteenth century, when its theological basis was forgotten. Nevertheless, in the purely mechanical sphere Newtonian theory was always potentially relativistic.

But in the nineteenth century, with the establishment of the wave theory of light, and, in particular, the electromagnetic theory of light, absolute space seemed to gain firmer foundations. The light waves, it seemed, required an ether to carry them. The ether seemed to provide the absolute standard by which absolute velocity could be measured. The phenomenon of the aberration of light (discovered by Bradley in 1729) appeared to show that the ether was not dragged along by any body moving through it. (The argument is exactly analogous to the observations one makes that rain, to anybody walking through it, appears to fall obliquely, and the deduction from this observation that rain is not dragged along by the walker.)

But if the ether is not dragged along by the earth, the velocity of light, as measured on earth, ought to vary with the direction from which the light comes. And this variation ought to be detectable in various optical experiments. Such experiments were tried from 1818 onwards, but no difference was ever detected. The crucial experiment was that of Michelson in 1881 (repeated by Morley, 1887, and others). In this a ray of light was sent out from a source and reflected at a mirror, and the double journey was timed (by an interference method). If the earth really moved through the ether, the journey in its direction of motion ought to take longer than the journey across its direction of motion. But no significant difference could be detected.

In 1893 Fitzgerald suggested that this difficulty could be explained away by assuming that any object moving through the ether is contracted (by a mathematically specified amount) in the direction of its motion. At first this was just a shot in the dark. But matter consists of particles held together by forces which were presumed to be electromagnetic in nature. If matter moves through the ether, these forces should alter. And Larmor and Lorentz were able to show that the alteration would be of the right amount to produce the Fitzgerald contraction.

Looked at from another point of view, the Michelson experiment could be interpreted to mean that the electromagnetic equations (which determine the velocity of light) ought to take the same form whether one considers them with respect to a fixed, or a moving system. Starting from this point of view, Lorentz produced in 1902 the famous 'Lorentz transformation'—a set of equations relating position and time as they would be viewed by two different observers moving relative to one another, and relating them in such a way that the electro-magnetic equations preserve the same form.

Now the Lorentz transformation, if it is properly interpreted (which in fact it was not till after Einstein's work), is mathematically equivalent to about half of the special relativity theory (the kinematic half). Meanwhile something approaching the other (dynamic) half had emerged from the theoretical work of Larmor and J. J. Thomson, according to which a charged particle in motion would behave as if it had an additional mass whose amount depended on its velocity; and this theory was verified experimentally for the motion of electrons by Kaufmann (1901–6).

Thus before 1905 many of the particular results which are incorporated in Einstein's special relativity were known. Their significance was only partially appreciated; their relations were not understood; and they were only obtained by a patching-up process without altering the old foundations, which were now proving inadequate.

Einstein's role was to clear away the old foundations and built on entirely new foundations a theory from which these results and many others emerged simply and naturally. In doing so he was considerably helped by the positivistic criticisms of Newtonian mechanics which had been carried out by Mach (1883) and others. Einstein did not accept the Machian philosophy in full, but acknowledged his indebtedness to its critical side.

"There are only five men in the world who understand Einstein's theory"—this legend dies hard. Perhaps the most curious thing is the choice of the number five: seven is more usual in such mystical statements. In point of fact Einstein's special relativity theory is a comparatively easy thing to understand, given a moderate mathematical equipment. It is a normal part of an honours mathematics degree at many universities. (And even the general theory of relativity, though it involves a much more difficult mathematical technique, is understood by 500 or 5000 rather than by five men.) So far as special relativity is concerned Einstein's genius lay, not in mathematical abstruseness, but in conceptual *simplicity*—in seeing that from two simple assumptions, one of which was daringly revolutionary, it was possible to deduce all the consequences which Thomson, Larmor, Lorentz and others had so laboriously worked out—and a great many others. One of these assumptions was simply the mechanical relativity principle that had been implicit in the Newtonian theory: *it is impossible to detect the unaccelerated motion of a body*, or absolute velocity is meaningless and science must discuss relative velocities. The other was simply to take the Michelson experiment at its face value and, forgetting all about the hypothetical ether, to assume that *the velocity of light in free space is the same for all observers, independent of the relative velocity of the source and the observer.*

In terms of 'commonsense', as it stood in 1905, the second assumption took a bit of swallowing. If light is coming towards you at 186,000 miles a second and if you then start to move towards the light at, say, 100,000 miles a second, even then the light will still be coming towards you at 186,000 miles a second (and not at 86,000 miles a second). And many of the consequences of these assumptions were even more difficult to believe. It followed, for example, that the measurement that an observer will make of the distance between two events depends on his velocity of motion. I estimate the length of a ruler on my desk to one foot. Another observer flashing past me at 93,000 miles per second would estimate it at about 10·4 in. Similarly he would believe that my wrist-watch is running fast. These things seemed to conflict with 'commonsense', because 'commonsense' had assumed that distance and time were something independent of the observer's velocity. But why should they be independent? Their independence is a useful assumption that works in ordinary life, because nothing moves fast enough to make any noticeable

difference. And it was a useful assumption in science, too, till the end of last century, for much the same reason. But there is no reason, other than this pragmatic one, for believing it. And now that experience has shown that Einstein's view is more successful than the old 'commonsense' view in explaining how things really behave, 'commonsense' is having to adjust itself. One effective method of helping this re-adjustment is to describe vividly universes in which Einstein's laws hold, but the constants of nature (such as the velocity of light) have values which make the various relativity effects appreciable in ordinary life. One then comes to see how the inhabitants of such universes, which differ only quantitatively from our own, would build up a quite different 'commonsense' to guide their everyday activity. This approach was brilliantly used by Professor G. Gamow in a series of articles in DISCOVERY in 1938 and 1939, which were afterwards collected into his fascinating book *Mr. Tompkins in Wonderland*. As a result of these and other efforts, most people today feel distinctly less uncomfortable about the so-called paradoxes of relativity than did the people of forty years ago.

Of course, the special relativity theory gained acceptance not because of any philosophical examination of the meaning of commonsense, but because it explained the observed facts better than the earlier theory, and because it made predictions which were verified by further experiments. There was, for example, Einstein's famous use of the $E=mc^2$ equation to predict that matter could be transformed into energy at a very favourable rate of exchange.

In creating the general theory of relativity (1915) Einstein owed much less to his predecessors than he did in the case of the special theory. He was dissatisfied with the fact that it would still seem to be possible to detect absolute accelerations. And there was the further point that it was really impossible to distinguish between the effects of accelerations and the effects of that mysterious gravitational force, which Newtonian mechanics had implanted in our 'commonsense'. Consider, for example, a series of experiments carried out in a lift. Suppose to begin with that there is no force of gravity, but that the lift is being accelerated upwards. Smith, who lives in the lift, releases his grip on a stone which he is holding. Since there is no gravity, the stone moves at the constant speed at which it was released—and we, observing from outside the lift, would feel no urge to postulate a force acting on it. But the floor of the lift rises with accelerated motion towards the stone, carrying Smith with it. So to Smith the stone appears to fall towards the floor. He, therefore, invents a force of gravity to explain why the stone falls; and his grounds for doing so are exactly those of Newton—namely, observation of the stone's (apparent) acceleration, coupled with an arbitrary decision to assert that there can be no acceleration without a force to produce it.

Now suppose, on the contrary, that there is a force of gravity, but that the lift is falling freely. Smith once more drops the stone. We ordinary mortals, looking at this lift passing by, observe both the lift and the stone falling together; and we say that the stone is being pulled down by gravity. But the stone falls at the same speed as the lift, and so to Smith it appears to stay motionless at the point where it left his hand. He, therefore, asserts that there is no force of gravity.

It thus appears that the existence or non-existence of gravity is merely a matter of the observer's point of view.

What Einstein did was to discover a point of view which made it unnecessary ever to assume the existence of gravitational force. He did so by a revision of the geometry of the universe. 'Commonsense' had assumed (because the idea had previously worked in practice) that the universe was Euclidean; that it had certain properties, such as the Pythagorean theorem that the square on the hypotenuse is equal to the sum of the squares on the other two sides. In 1908 Minkowski had shown that the special theory of relativity could be given a very simple geometrical form, provided another (non-Euclidean) geometry were substituted for that of Euclid. In evolving his general theory of relativity, Einstein generalised Minkowski's work. He used the more general geometry of Riemann (dating from the middle of the nineteenth century) in which Pythagoras's theorem is not true, but in which there is a rather more complicated relation between the sides of a (small) right-angled triangle. He further assumed that the exact nature of this last relation in any part of the universe is determined by the positions of the masses of matter that surround it. Using the mathematical technique of the tensor calculus (developed by Ricci and Levi-Civita at the end of last century) he was able to show that such a universe does not need gravitational forces—any phenomenon that Newton explained by gravitation is more simply and more accurately explained in terms of the mere geometry of the Einsteinian universe. In it, any body that is not subject to a real force (that is, a physical push)* follows a curve called a geodesic, which is the natural analogy in the new geometry of a straight line. A geodesic, in fact, is defined by a generalisation of the 'shortest distance between two points' property of a straight line. In Einstein's description of the universe a geodesic, instead of a straight line, became the natural path for a body to follow. And Einstein's achievement was to show that this theory, without any hypothetical force of gravity, gave a better description of the universe than did the Newtonian theory. It explained, for example, the peculiar behaviour of the planet Mercury, on which Newtonian theory failed. And it predicted correctly that light would be deflected in passing a heavy body like the sun.

Here we can see 'commonsense' executing a pendulum motion. It would be absurd to say that Aristotelian mechanics was in any sense an anticipation of general relativity. Nevertheless, if he could acquire the necessary mathematical technique, a man who thought in terms of Aristotelian 'commonsense' would have had more sympathy with Einstein than did the men brought up in the Newtonian 'commonsense' of the nineteenth century. Einstein said that, given the right geometry, a body follows a certain natural path (a geodesic) unless it is being pushed by a tangible force. The Aristotelian, who believed that a stone fell to earth because that was the natural thing for it to do, would have found Einstein's viewpoint congenial. The Newtonians, having arbitrarily asserted the naturalness of unaccelerated straight line motion and having introduced gravity to deal with the difficulty that this type of motion never occurs in nature, found the Einsteinian idea contrary to 'commonsense'. And most of us are still

* For present purposes we must ignore electro-magnetic forces—even though a 'push' is of a fundamentally electro-magnetic nature.

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Sir Ben Lockspeiser

APPLETON'S SUCCESSOR AT D.S.I.R.

It is rare for a scientist in Government service to gain fame and fortune, though such a career does guarantee certain advantages which are evidently attractive to scientists—as is proved by the fact that the British Government has at the moment no real difficulty in finding recruits for the Scientific Civil Service. Even the scientists in the top grades of Government service must expect to forego fame and fortune, while those of the highest rank must necessarily forsake the pleasures of the research laboratory for the more difficult and thankless profession of administration. The future of British science will depend to an ever increasing extent upon the men we choose to direct research and development, for these men are the captains in the campaign to exploit science for the public good. The appointment of Sir Ben Lockspeiser as successor to Appleton as head of Britain's Department of Scientific and Industrial Research is therefore important. This choice could not have been bettered; the whole of his previous career has been a perfect training for the position of D.S.I.R. Secretary. Moreover, as Chapman Pincher has said, his story should be an inspiration to every young scientist entering Government service.

He is 58 this month, having been born on March 9, 1891. Educated at the Grocers' School, and then at Cambridge and at the Royal School of Mines, he entered Government service after serving in the Army.

At the outbreak of the first World War he immediately volunteered for the Army and in response to a demand for men with expert knowledge of water-testing joined the R.A.M.C. as a private. He went to Gallipoli to carry out this work. While he was there he was offered an infantry commission, but refused it. Then he was transferred to investigations on dysentery, which were directed by Major Archibald of the Burroughs Wellcome Laboratory in Khartoum. The dysentery which was causing many fatal casualties among our troops in the Middle East was originally identified as bacillary dysentery, but the microscopical investigations of Lockspeiser and his colleagues established that it was actually caused by the amoebic parasite.

In December 1915 Lockspeiser was invalided home after he himself had gone down with severe dysentery—this was not surprising as he had to work in a very primitive wooden laboratory in which flies covered with dysentery germs roamed at will unhampered by any form of fly-proofing.

1916 saw the Services being combed for men with scientific ability, and early in that year Lockspeiser was posted to the Admiralty Steel Laboratory at Sheffield. His grade was that of Scientific Assistant, at that time the lowest in the Scientific Civil Service. In November 1920 he became a Research Assistant (equivalent to the modern Scientific Officer) at the Royal Aircraft Establishment at Farnborough.

For a good many years he was a 'backroom boy', working doggedly on a variety of tricky problems which had to be solved before the revolution in aircraft design symbolised by Mitchell's Spitfire could begin. He was indeed one of 'the first of the few'. Wing flutter, the preventing of 'icing' on aircraft, the design of sensitive instruments for measuring pressure—these were the kind of things on which Lockspeiser worked. Then, in the mid-'thirties, the Air Defence Department was set up at Farnborough to deal with the urgent problems connected with the air defence of Great Britain, and Lockspeiser was put at its head. Just before the outbreak of war in 1939 he was appointed Assistant Director of Scientific Research at the Air Ministry, his immediate superior being Sir Henry Tizard. In 1943 he became Deputy Director of Scientific Research at the Ministry of Aircraft Production, and two years later he was promoted Director-General of Scientific Research in this Ministry. When M.A.P. was assimilated into the Ministry of Supply, he took charge of all aeronautical research, his official M.O.S. title being 'Director-General of Scientific Research (Air)'. Some idea of the responsibilities associated with this job can be gained from the fact that at one period he was controlling a force of over 4000 scientists and engineers; another index of the magnitude of his responsibilities is the figure of £28,000,000 given in the 1946–7 Estimates for expenditure on air research and development in Lockspeiser's department—this rate of expenditure was, of course, considerably increased.

The Lockspeiser programme of research and development must account for something like £200,000,000. It is important to realise, too, that his task was peculiarly difficult, since he had to plan for new developments at a time when aeronautics was entering a new revolutionary phase in which jets would have to supersede piston engines, and planes would have to undergo radical metamorphosis and become all-wing tail-less aircraft capable of penetrating the supersonic barrier.

To find much more detail about Lockspeiser's career is in itself something of a major research problem, for it can only be found after long searching in unexpected places. One finds, for instance, an interesting tribute to Lockspeiser's ingenuity in Wing Commander Guy Gibson's book. Gibson tells this story in connexion with the raid on the Mohne and Eder dams.

> Unless we could get some method of flying accurately at 150 ft. over water the whole project would have to be called off. Many methods were tried in vain. Then one day it was solved. Mr. Lockspeiser of M.A.P. thought an old idea would work: spotlights placed on either wing, pointing towards the water where they would converge at 150 ft. The pilot could see the spots and when they merged into one he knew the exact height. Within a week everyone could fly within a few feet of the water with amazing consistency.

Music runs in the Lockspeiser family, his brother, Edward, being a well-known musical critic and authority on Debussy. This photograph was taken while Sir Ben Lockspeiser was entertaining atomic scientists at Harwell.

Such was the simple solution—so simple that it is obvious, now!—which Lockspeiser was able to suggest; the problem, it should be noted, was not in his scientific field at all, but it is the sort of solution one would expect from a good all-round scientist.

Lockspeiser is a most affable person, always an asset in an administrator. This quality made him an instant success at the press conference which he gave after the war. This conference must rank as virtually unique in that he adopted the technique of delivering to the assembled newspapermen a full-length lecture on Aeronautics and the Future; he even went so far as to use all the paraphernalia of a university lecture theatre, a revolutionary innovation at a press conference—which others should adopt. He made the lecture an expression of his faith in the ability of the young enthusiastic research workers upon whom Britain's future in the air depends, and also of his faith in the future of the aeroplane and the contribution it has to make to our national economic life, stressing all the time that the aims of research on the civil side must be towards economy, safety and reliability.

Particularly interesting is the prediction he made on this occasion about the helicopter.

> It is quite possible, indeed it has already been done in a primitive way in Germany, to fold back the wings of the rotor and drive the helicopter along a road from one's garage to a suitable take-off point. This may sound fanciful, but the first motor car preceded by a man with a red flag was not more fanciful. The possibilities in an aircraft which is not tied to any specially prepared aerodrome and can land and take off in any clear space slightly bigger than its own dimensions are obviously far reaching. I would expect the helicopter to become the air taxi of the future, transporting passengers from the main airports situated outside towns (because of their large size) to town centres. Large stores, clubs and office blocks will doubtless provide themselves with flat roofs for the landing of helicopters.

At this press conference he also brought home very effectively the great potentialities of air photography; he conjured up, for example, the quite practicable idea of a complete survey of all the farmland in Britain being made on 400 magazines of film exposed from the air.

Lockspeiser is a man of imagination; but though he looks towards the stars, his feet are firmly on the ground, and his ideas of what might be done are always tempered with a realisation of what is practicable in the short term of five, ten or twenty years. A capable administrator endowed with his kind of vision and breadth of interest should find the secretaryship of D.S.I.R. a most satisfying post. Under Lockspeiser's direction the coming years should be very fruitful ones in D.S.I.R. For the new Secretary they are bound to be busy years, and he is likely to have even less time than in the last decade for the gardening and music-making which are his chief relaxations.

WILLIAM E. DICK.

The Mackerel

NEW LIGHT ON ITS MIGRATIONS AND HABITS

By G. A. STEVEN, B.Sc., F.R.S.E.*

THE common mackerel (*Scomber scombrus L.*) is one of England's important food fishes. Just prior to the outbreak of the second World War her total landings were some 140,000 cwt. valued at about £80,000. Remarkable as it may seem, rather more than one-third of this total was landed at the small port of Newlyn, Cornwall (Fig. 1). It is still more surprising to note that during the four years 1923–6 more mackerel were landed at Newlyn than at all other ports in England and Wales put together.

Because of its importance numerous previous researches into the life and habits of the mackerel have been carried out but many mysteries remained that could not be unravelled. Chief of these has been the mystery surrounding its migrations. In late spring, summer and autumn mackerel are plentiful around the whole coastline of southern and south-western England in shallow waters hard by the land, but disappear from them on the approach of winter. When our present investigations began (in 1936) those mackerel were believed to spend the winter months far out somewhere in the deep waters of the Atlantic Ocean and to begin migrating shorewards again in the following spring in order to spawn when they arrived once more in shallow coastwise waters hard by the land.

These over-simplified conclusions, which have endured for so long, have been supported by the activities of the deep-sea drift fishery from Newlyn, during the months of March till June. Fig. 2 A–G has been prepared to illustrate the sequence of events that takes place in this fishery during the course of the fishing season. In each of the charts the black dots represent the positions in which ten representative drifters cast their nets during fortnightly periods. In the first half of March the fishing fleet is scattered diffusely over a wide area, apart from some vessels fishing close to the Irish Coast. Later in March, and especially in April, the fleet is concentrated on the main shoals of fish far out to the westward of the Scilly Islands. As the season advances the shoals are encountered progressively nearer the south-western tip of England, splitting as they approach the land into 'northern' and 'southern' components.

But this migration shorewards from deep water is not the only one that takes place around the south-western region of England in spring. At the same time other mackerel are migrating *down* channel past Start Point and Lizard Head *in exactly the opposite direction.* Still others are simultaneously moving southwards past the northern shore of the Devon-Cornwall peninsula before they too turn seawards to join up with their fellows moving in from the westward (Fig. 3).

These apparently conflicting migrations of different bodies of fish can now be readily understood in the light of our discovery that the mackerel do *not* spawn in shallow coastwise waters; they have one large common spawning ground in the open sea a hundred miles or so to the westward of the Scilly Islands. This spawning area which has now been carefully surveyed and charted lies close by the 100-fathoms contour which, in this region, marks the beginning of the continental slope where the sea bed dips steeply down from 100 fathoms to 1000 fathoms and more.

Research has also shown that many mackerel spend the winter months on the sea floor in both shallow and deep water and that certainly not all of them return to the Atlantic Ocean as was previously believed. During this bottom-living stage the fish are densely packed along submarine slopes, which may be either above or below the general level of the sea bed such as the sides of sand banks or of submarine gulleys.

Such slopes are found at various places in the English channel—e.g. Hurd Deep, Vergoyer Bank, Dieppe Banks —around the Smalls near Milford Haven, and at various places south of Ireland as far out as the edge of the Continental Shelf itself.

The densely packed phase of the bottom-living period lasts only a short time—a few weeks at most. Thereafter the fish spread outwards over the surrounding sea bed and then break up into shoals that rise to the surface and migrate once more to the spawning grounds.

Over the course of one full year, therefore, the life of

* *Mr. Steven is one of the zoologists of the Plymouth Laboratory of the Marine Biological Association.*

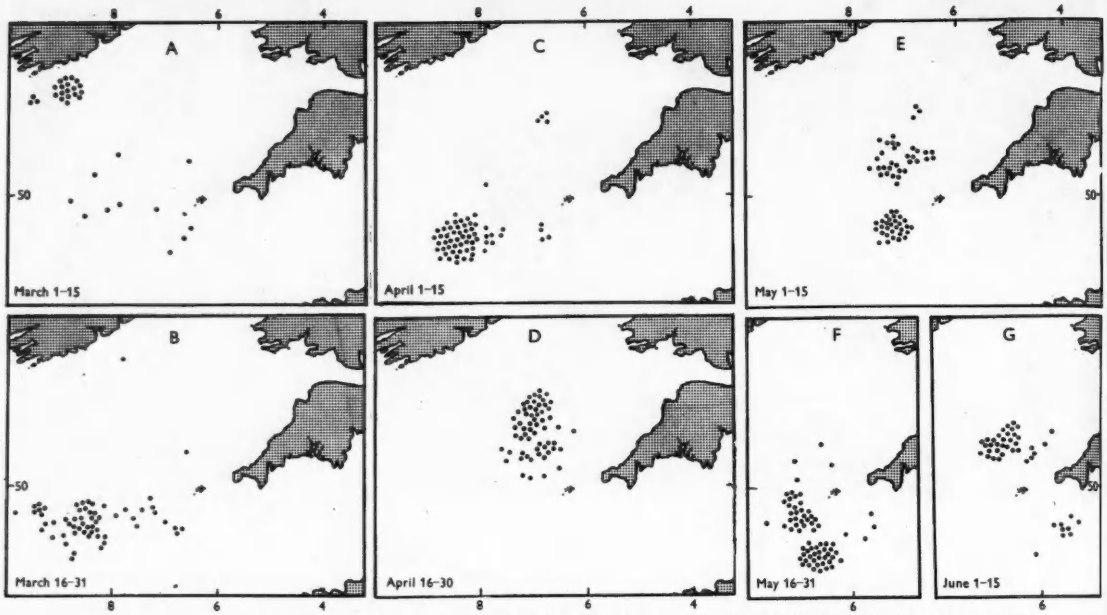


FIG. 2.—Locus of mackerel fishing in 1938 by Newlyn-based steam drifters; *A*, in the first half of March; *B*, the second half of March; *C*, the first half of April; *D*, the second half of April; *E*, first half of May; *F*, second half of May; *G*, first half of June. Each dot represents a 'shot' by one of ten representative drifters.

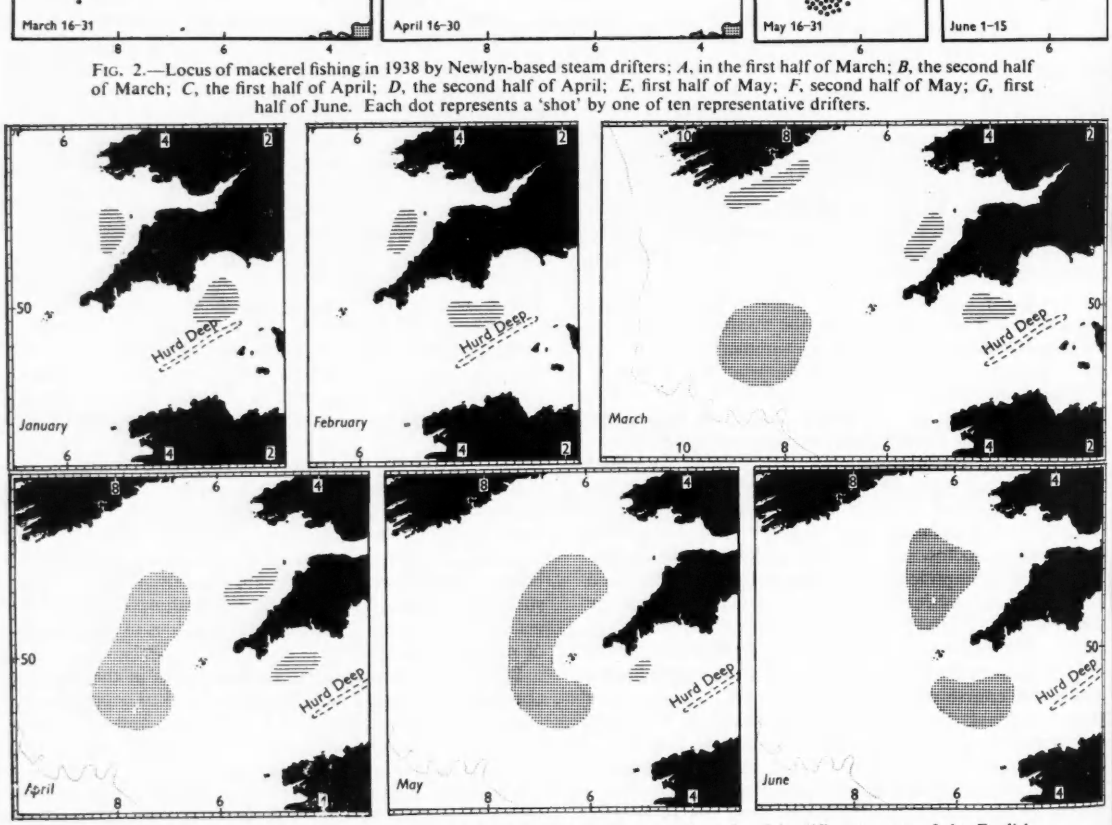
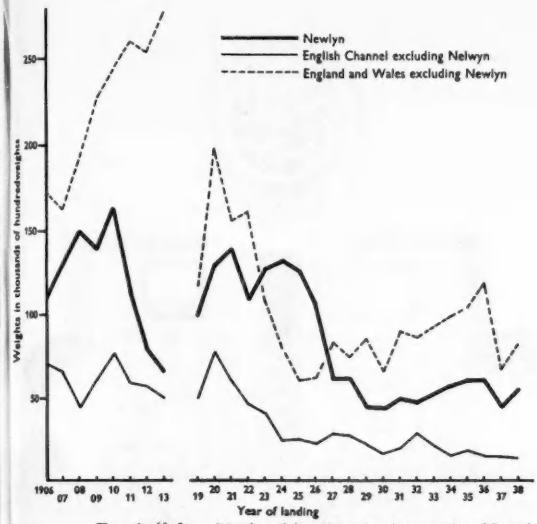


FIG. 3.—Generalised chart showing presence and migratory movements of mackerel in different parts of the English Channel and Celtic Sea. The hatched areas in the English Channel denote westward movement of 'Channel' mackerel (January–May inclusive). The hatched areas to the northward of the Devon-Cornwall peninsula denote southward movement of mackerel that later turn westwards into deeper water (January–April inclusive). The stippled areas in the Celtic Sea denote the shoreward migrations of large bodies of mackerel from the westward (March–June inclusive).

The Mackerel's Migration



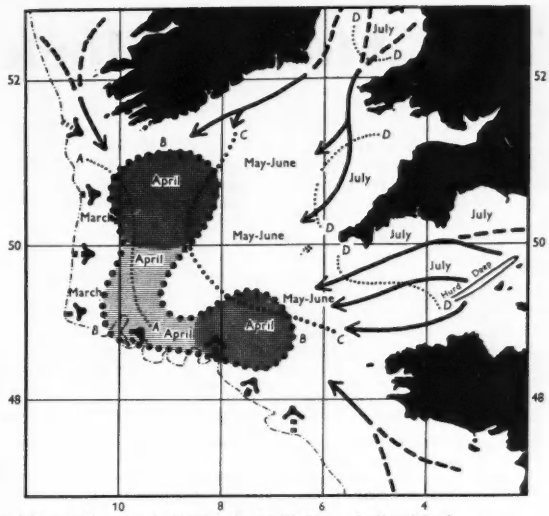


FIG. 1. (*left*).—Mackerel landings in thousands of hundredweights at Newlyn; in England and Wales excluding Newlyn; and at English Channel ports, including Newlyn. Data derived from *Sea Fisheries Statistical Tables* for 1906–38. FIG. 4. (*right*).—Generalised diagram indicating the migrations of mackerel in the English Channel and Celtic Sea in relation to the spawning ground. The darkly stippled areas are the chief spawning centres (April). A little spawning takes place farther west in March and progressively to the eastward until July. Arrows represent migration routes. Broken lines indicate migrations about which some doubt still remains. —·—·—·—·—·— = the 100-fathom contour.

adult mackerel in the south-west region falls into two main periods, a demersal period and a pelagic period, with a brief transition period during which the fish return to the bottom and reform shoal. This can conveniently be summarised as follows:

I. DEMERSAL PERIOD	(i) *Compact phase*	Intensely dense and extremely circumscribed concentrations of fish massed on the sea floor in very localised positions distributed over wide areas. November, December.
	(ii) *Deployment phase*	Concentration diminishes; still keeping to the bottom the fish spread slowly outwards over adjacent areas before ascending to the upper waters and giving rise to pelagic shoals. December, January, February.
	(iii) *Shoaling phase*	Active migration of the shoals to the spawning grounds and return (or continuation) shorewards. January–July.
II. PELAGIC PERIOD	(iv) *Disperse phase*	Shoals broken up and fish dispersed in inshore waters around all coasts. June–October.
III. TRANSITION PERIOD	(v) *Reconcentration phase*	Disappearance from inshore waters and return to phase (i). October, November.

In the spring of the year, therefore, mackerel are to be found migrating from the north, south, east and west to this common spawning ground (a hundred miles or so west of the Scilly Islands) of whose existence we knew nothing before this investigation was begun (Fig. 4). During these migrations the fish do not come close inshore; this only happens on their return from the spawning ground.

An important point is that this spawning ground, right out in the open sea, is situated near the 100-fathom contour and the fish come inshore into shallow coastwise waters only *after* spawning.

In the North Sea, however, mackerel do migrate close inshore to spawn, the most important North Sea spawning ground being hard by the land on the north side of the Skagerrak towards the Norwegian Coast. But reference to a chart of the North Sea will show that although this migration is a shoreward one from adjacent off-shore waters, it is at the same time a migration from shallower water to the vicinity of the 100-fathom contour. There is thus a very marked similarity between what we now know to be the chief spawning locality of the south-west region and of the North Sea area. Although the former spawning ground is far out in the open sea and the latter is hard by the land, both lie close to the 100-fathom line. In both areas, too, this contour closely follows the edge of a well-marked slope in the sea bed from shallow to deep water, i.e. to the depth of the Atlantic Ocean in the one locality and in the other to the lesser but not inconsiderable depths of over 400 fathoms that are present in the Skagerrak and are to be found nowhere else in the whole of the North Sea.

A survey of the available information concerning mackerel on the American side of the Atlantic Ocean suggests very strongly that the habits and migrations of these fishes in that region, too, follow essentially the same pattern. Their chief known spawning grounds are in the Gulf of St. Lawrence and in the Gulf of Maine, particularly in the Massachusetts Bay area. Existing information extends only to spawning grounds well inside the 100-fathom contour. But the indications are that these are only of secondary importance and that in those regions, too, further researches will reveal that the chief spawning grounds are situated in the close vicinity of the 100-fathom line. Examination of charts of both the Gulf of St. Lawrence and the Gulf of Maine shows that they are well suited to the needs of the mackerel as revealed by our British investigations in that the 100-fathom contour extends inwards into both.

The diagrams are reproduced from the Journal of the Biological Association, 1948, Vol. 27, by kind permission of the Council.

The Atomic Clock

FIG. 1.—The Astronomer Royal, Sir Harold Spencer Jones, predicts that the atomic clock developed at the National Bureau of Standards in Washington will replace the quartz-crystal clock and will give a time standard of extreme accuracy. Theoretically it has a potential accuracy of one part in 1000 millions or even 10,000 millions. The clock is controlled by a constant frequency derived from a micro-wave absorption line of ammonia gas. Its essential components are: a crystal oscillator, a frequency multiplier, a frequency discriminator and a frequency divider. These are housed in two cabinet racks on top of which are mounted a special 50-cycle clock and a wave-guide absorption cell containing ammonia gas at a pressure of 10–15 microns.

From top to bottom, on the left panels: frequency deviation recorder; 1000-cycle synchronous motor clock, 24-hour dial; electronic frequency meter driving deviation recorder; 100-kilocycle quartz-crystal oscillator; frequency dividers, dividing 100 kc. down to 50, and 1000 cycles; regulated power supply for klystron tubes; regulated plate and filament power supply. *On the right panels:* frequency comparator and deviation indicator; monitoring oscilloscope; pulse amplifiers and shapers, and pulse discriminator; d.c. control voltage indicator; sweep generator, FM modulator, and klystron frequency multiplier, 270 mc. to 2984 mc.; frequency multiplier, 100 kc. to 270 mc.; electronic vacuum gauge; regulated plate and filament power supply.

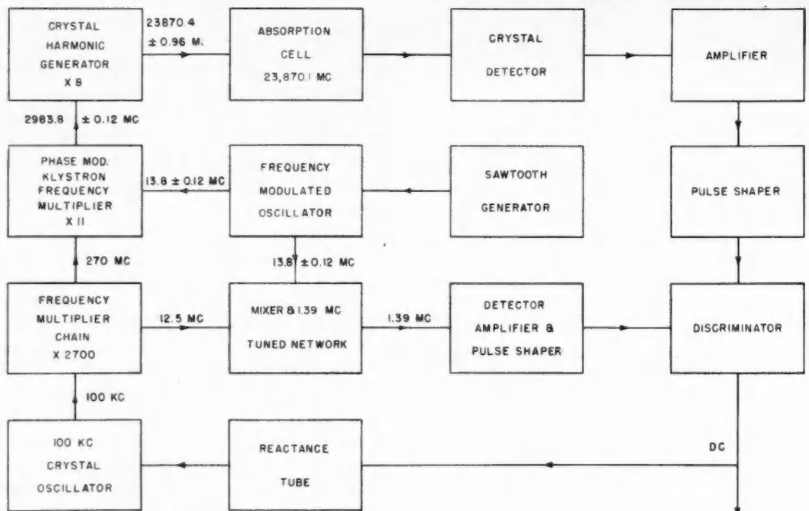
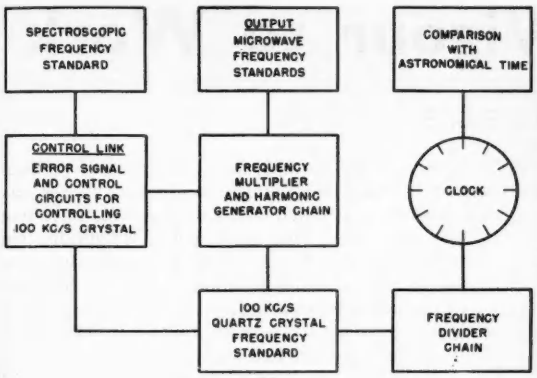


FIG. 2.—Complete block diagram for the atomic clock. The fundamental driving signal for the clock originates in the 100-kilocycle quartz-crystal oscillator (*lower left*). A frequency-multiplying chain using ordinary radio tubes multiplies the signal up to 270 megacycles; a frequency-multiplying klystron then multiplies the signal eleven more times and combines it with a signal from a frequency-modulated oscillator to produce an FM output signal. A silicon-crystal harmonic generator multiplies this signal and introduces it into the ammonia absorption cell. As the frequency of the modulated control signal sweeps across the absorption-line frequency of the ammonia vapour, the signal reaching the silicon-crystal detector at the end of the absorption cell is decreased, giving an output pulse which is strengthened and sharpened in the amplifier and pulse shaper. A second pulse is generated by combining in a mixer the output of the FM oscillator and a 12·5 megacycle signal from the frequency-multiplying chain. The time interval between the pulse from the absorption cell and the pulse from the mixer can then be measured in the discriminator. The discriminator gives zero output when the time interval is right; but when the interval is wrong, it sends a control signal to the reactance tube, which retunes the crystal oscillator accordingly. The crystal oscillator is then stabilised against drift and can maintain the timekeeping of the synchronous-motor clocks with extreme accuracy.


SPECTROSCOPIC FREQUENCY STANDARD
OUTPUT MICROWAVE FREQUENCY STANDARDS
COMPARISON WITH ASTRONOMICAL TIME
CONTROL LINK
ERROR SIGNAL AND CONTROL CIRCUITS FOR CONTROLLING 100 KC/S CRYSTAL
FREQUENCY MULTIPLIER AND HARMONIC GENERATOR CHAIN
CLOCK
100 KC/S QUARTZ CRYSTAL FREQUENCY STANDARD
FREQUENCY DIVIDER CHAIN

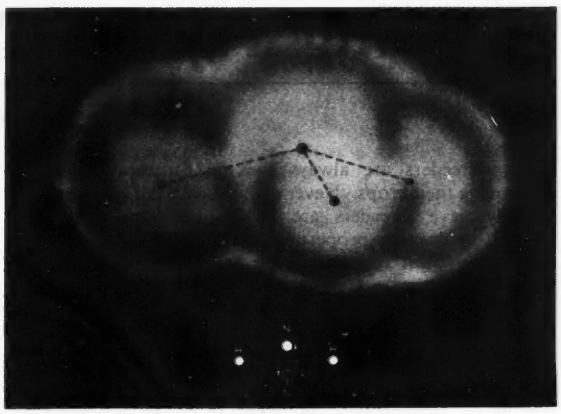
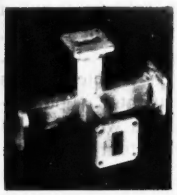
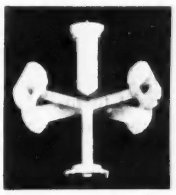


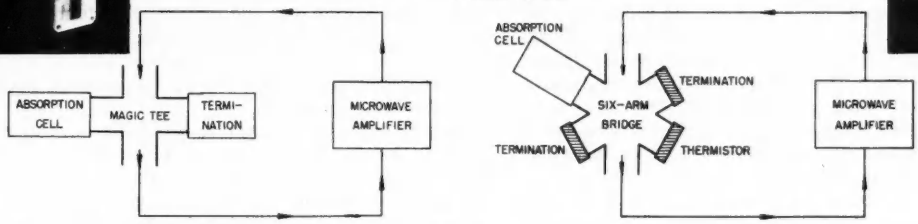
FIG. 3 (*left*).—Simplified block diagram of the clock. The crystal oscillator is locked to the constant-frequency of the ammonia line. A frequency-divider chain drives the synchronous-motor clock, first reducing the stabilised 100-kilocycle signal to the clock frequency. FIG. 4 (*right*).—The clock works on the strongest of the many absorption lines in ammonia. This line corresponds to the quantum transition associated with the 'turning-inside-out' of the ammonia molecule, shown schematically in the bottom diagram. The top diagram shows the arrangement in space of the nitrogen and hydrogen atoms making up of the ammonia mocule.

Atomic oscillators for frequency-control applications in the micro-wave region (where quartz-crystal oscillators cannot be used) are being developed. One such oscillator, for making atomic clocks and frequency standards, employs a wave-guide assembly known as the 'magic tee' (FIG. 5, *left*). Feed-back through the 'magic tee' to the micro-wave amplifier occurs only at the resonant frequency of the gas in the absorption cell.

FIG. 6 (*right*).—Another type of atomic oscillator resembles the 'magic tee', but uses a six-arm wave-guide bridge to control the amplifier feed-back. This is especially suitable for primary atomic clocks.







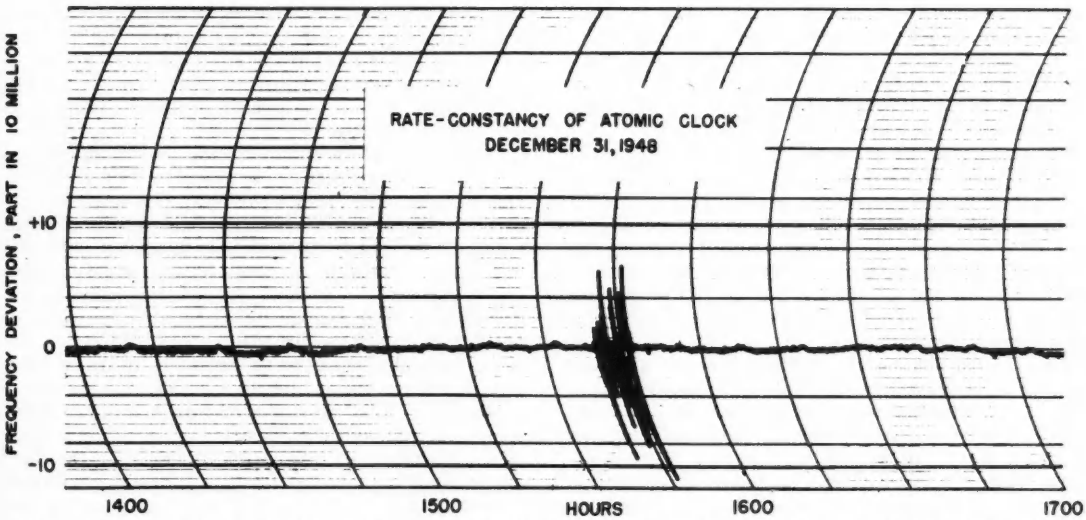


FIG. 7.—The rate-constancy of the atomic clock in terms of its frequency deviation in parts per ten million shows the timekeeping accuracy during an actual test run. The narrow portions of the deviation trace, recorded while the clock was locked to the ammonia absorption line, indicates a constancy of better than one part in ten million. When the control circuit was unlocked, large frequency variations occurred, as shown by the broad part of the recorder trace.

Putting Hybrid Vigour to Work

GORDON HASKELL, B.Sc.

PLANT breeders are always looking for new ways of improving their crops. Never content with the strains they already have, breeders are always searching for new varieties with better properties than those already existing. They may want to obtain new fibre crops with longer fibres; crops that are more resistant to fungus or virus disease; winter varieties that are more resistant to cold, or plants more capable of withstanding damage during stormy weather.

Yield is by far the most important character which plant breeders wish to improve. Bigger and better crops are always in demand, especially as nowadays, after war-time devastation and with increasing populations, it is important to obtain high yields from all crops. It must be admitted, however, that there are some people who prefer agricultural products to be in short supply so that prices remain high, and from them the plant breeder remains aloof.

During the last few years plant breeders have awoken to the fact that genetics, the science which studies the laws of inheritance in animals and plants, might be able to assist them. Many of the new ways of present-day plant improvement result from a synthesis of the 'art' of plant breeding and the 'science' of genetics. In a country like England traditional methods, which have been valuable in the past, are still preferred by the seed firms. In the United States, where traditional breeding methods have not had time to become established, American plant breeders have been quick to grasp the implications which genetical studies have provided. It is no wonder, then, that some of the more interesting examples of plant improvement have originated in North America. For instance, American breeders have produced improved forms of some flowers, such as *Antirrhinum*, by using the drug colchicine to double the number of chromosomes (see Dr. P. T. Thomas's article on this subject, DISCOVERY 1945, pp. 376–82). Similarly, they have been able to produce strains of *Portulaca* with double flowers that also have seed; previously these were sterile.

The traditional way of improving plants is by means of *selection*. When primitive man took to collecting seeds and saving them through the winter, he made a great advance. Although not often realised, he made an even greater step forward when he set aside the best seeds for re-sowing and used the poorer seed as food. Previously he had eaten the best grains and left the less plump ones for sowing. This was the first kind of selection in the history of domesticated plants.

Most of the older works on plant breeding and seed production describe elaborate methods of selecting plants for seed; this method was known as *roguing*. In stocks grown for seed, this meant weeding out those plants not coming true to type before they flowered. Darwin described these in his *Animals and Plants under Domestication*.

There are several methods of selection for improving crops. One way is to save seeds from the best plants of a variety each year and use these as seed the following year. This means that selection is through the maternal side only, except in crops such as peas and barley which pollinate themselves. Another method is carefully to select a few mother plants and let these interbreed. In this way a nucleus is obtained which produces seed superior to that of the original variety. One other method is hybridisation followed by selection. Plants of one particular strain are crossed with those of another strain or variety. Superior plants can then be selected as seed parents from the progeny which segregate. This is how several wheat varieties, such as Marquis, have been produced.

One of the most interesting examples of selection is that for high oil and protein content in maize. In this crop it was possible to increase the amount of oil from 4·70% to 9·86% in twenty-eight years of selection, and the amount of protein from 10·9% to 16·6% in the same time.

But selection has several disadvantages. For instance, it will only produce results if the original variety outbreeds. In this type, each plant normally receives its pollen from other plants and does not set seed from its own. Cabbages, radishes and maize are examples of this type. Their chromosomes are always kept in a heterozygous condition, as continual mingling of parents at pollination reduces the chances of chromosomes with identical genes from pairing with one another. Selection is therefore possible in such crops, for by picking out plants showing the best recombinations of chromosomes, and so giving the characteristics sought after, the breeder gradually modifies the strain.

On the other hand, selection is of little value in species such as tomatoes and peas which inbreed. This is because the pollen fertilises its own flower, so that unless a mutation, or sudden noticeable hereditary change, occurs, the paired chromosomes are similar or homozygous. There are, therefore, no new recombinations for the breeder to select. Variations in these kinds of crops are often due purely to environmental effects. However, if artificial crosses are made between the various strains, selection may sometimes be effective, as new assortments of paired chromosomes are then brought together.

A disadvantage of continued selection in outbreeding species has recently been demonstrated by Prof. K. Mather and his colleagues. They have shown that selection for a particular quantitative character (e.g. increased bristle number in the fruit fly, *Drosophila*, or number of cotyledons in plants), brings with it unpredictable associated changes called *correlated responses*. As these usually involve decreased fertility, lengthy selection for any particular plant character tends to give reduced seed production. This is what actually happened to the strains of maize which give high figures for oil and protein content in the seed.

Maize, or 'corn' as it is called by Americans, differs somewhat from other outbreeding crops in being completely dependent on man for its continuance. Occasionally seedlings are found as weeds, but these rarely manage to establish themselves. It might therefore be expected that by continual selection man has enlarged maize yields which have perhaps now reached the limits the species is capable of giving.

In America, prizes used to be given for the biggest ears

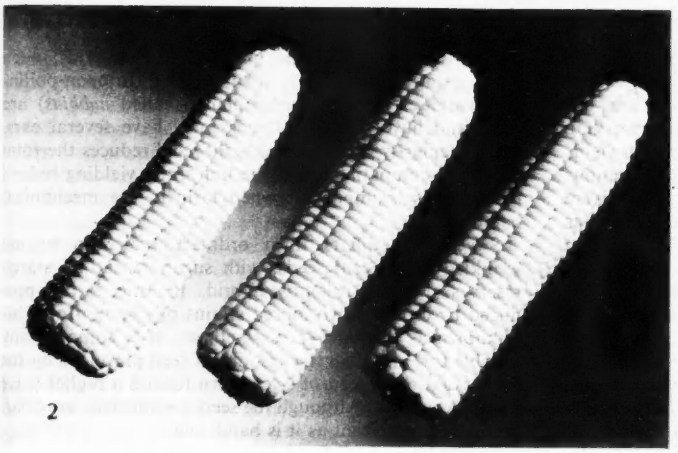
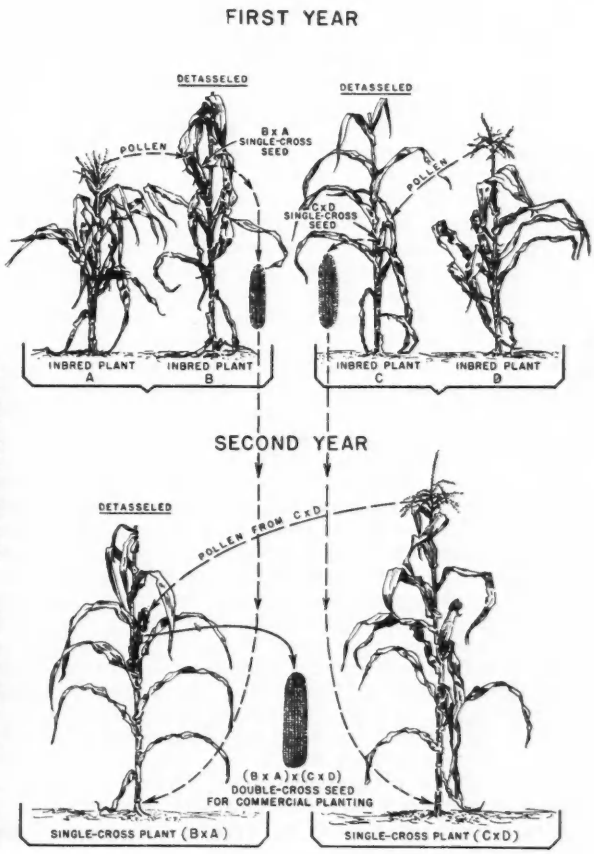


FIG. 1 —The two inbreds on either side were crossed to produce the vigorous hybrid in the centre. (*Courtesy, Pioneer Hi-Bred Corn Company.*)

FIG. 2 —Ears of hybrid corn, showing remarkable uniformity. (*Courtesy, Associated Seed Growers, Inc., New Haven, Connecticut.*)

FIG. 3 (*below*).—Crossing two inbreds to produce a 'single cross'. (*Courtesy, Pioneer Hi-Bred Corn Company.*)

FIG. 4 (*right*).—The technique of producing 'double-cross' hybrids. (*From "Yearbook of Agriculture", U.S. Dept. of Agriculture, Washington,* 1937.)



Hybrid Corn

exhibited at the 'corn' shows. It was hoped that by sowing from these selected large ears, with their numerous large seeds, yields would be increased. Yet larger increases did not occur. To test this, Prof. T. A. Kiesselbach, working in Nebraska, selected maize for eight years for high yields by several methods. He then compared these selections with the original variety continued unselected. There were no marked differences. As selection on ear basis was ineffectual, new breeding methods, therefore, had to be found to improve maize yield.

Now it had been known, since the independent pioneer work of Dr. G. H. Shull and Dr. E. M. East at the beginning of the century, that when maize is inbred (by applying pollen to the female flowers on the same plant) the vigour of the offspring falls off. This process is known as *selfing*, and produces reduced yields and decreased plant growth. When it is repeated for several generations a further fall in vigour continues, but the rate of fall decreases. Eventually, by the time that the fifth to seventh generation of selfing is reached, these so-called *inbred lines* show remarkable uniformity within themselves; each plant is very similar to its fellow.

Numerous aberrant forms appear during the inbreeding process. These are weeded out, so 'purifying' the material. They are due to inbreeding bringing into one nucleus gene-pairs* with deleterious effects; these do not often come together in open-pollinated maize varieties. Actually a stock which carries large numbers of these hidden characters need not necessarily give rise to poorer inbred lines than those carrying fewer of them.

Plants from two such separate inbred lines, and preferably originating from different open-pollinated varieties, can be crossed together. When the resulting seeds are planted, the hybrid offspring are not only uniform, but are much more vigorous and give a higher yield than the inbred parents. This phenomenon is known as *hybrid vigour* or *heterosis*.

Now it is also known that when certain dwarf 'mutants' of maize are crossed together, their offspring are quite normal, tall plants. Yet their offspring throw up the dwarf forms again in proportions according to the laws of inheritance. This behaviour gives a partial clue to the basis of hybrid vigour. Inbreeding accumulates similar genes in each line although different lines have different sets of similar genes; when different inbreds are hybridised, each pure (homozygous) pair of genes is broken up and each is now partnered by another gene. This restores the normal condition for maize with mixed (heterozygous) gene-pairs.

Some inbreds form better hybrids than others. The term used for this phenomenon is *combining ability*. Once inbred lines have been produced (or even during the first stages in their production) it is necessary to test them for combining ability. Inbreds which are poor combiners are discarded, the aim being to get good combiners which themselves have good characters.

The hybrids are not only heavier yielding than either parent inbreds; they also are better than one or both the original varieties from which the inbreds were derived. This is partly due to the uniformity of hybrids; each produces at least one good ear per plant. In open-pollinated varieties of maize some plants (called *nubbins*) are weak and have no ears. Others may have several ears. The irregularity of individual plant yield reduces the total output in comparison with the uniformly yielding hybrid plant. This is important when farmers use mechanical harvesters.

Sweet corn differs from ordinary maize in having wrinkled translucent seeds, with sugar instead of starch reserves. Most of it is now hybrid. In America it is produced by crossing two inbred strains of sweet corn. This is known as the *single-cross* method. It is commercially feasible for, although the amount of seed produced by the inbreds is small, seed of sweet corn fetches a higher price than maize seed. Although the seed is somewhat irregular, this is not important as it is hand-sown.

In England, the John Innes Horticultural Institution is investigating the use of this type of hybrid vigour. Although a few single-cross North American hybrid sweet corns do well in this country, it has been found necessary to start a programme to produce English strains of hardy inbreds from specially adapted hardy varieties. This takes time, and results will not be available for several years.

Seed obtained from a single-cross has several disadvantages. Inbreds show reduced fertility; not only are ears reduced in size but not all their seeds mature. The result is that the seeds are often highly irregular instead of regular outline, through lack of mutual pressure when the seeds are growing and expanding against each other in the cob. This is a disadvantage especially in the mid-western States where large fields are sown by mechanical sowers. Seeds must accurately fit the sowing plates, otherwise they fail to drop as the sower moves along. As maize is spaced at intervals of a foot, even slight irregularities in the sowing cause an appreciably smaller yield at harvest. Farmers were therefore not going to purchase this new kind of seed.

At one time this was such a deterrent that it seemed unlikely that hybrid seed would be used on a large scale. However, Dr. D. F. Jones of the Connecticut Agricultural Experiment Station devised a scheme which remedied the situation. It was known that if hybrid corn is selfed, the hybrid vigour becomes reduced and the second and later generations lose the uniformity so characteristic of the first. Hybrid vigour is transient, so that seeds must be crossed afresh for each sowing to produce fully vigorous and uniform plants. But Dr. Jones found that, if he raised plants from two different single-crosses and hybridised these, their offspring are sufficiently uniform and vigorous to warrant using them. They are, however, somewhat less uniform and do not quite manifest hybrid vigour to the fullest extent. Yet they are much better than open-pollinated varieties. They also have the great advantage that seed is of first-grade quality as it is produced on hybrid mother plants which are fully fertile. The seed has good germination and is suitable for mechanical sowing. This method, known as the *double-cross*, is now used extensively for hybrid field corn.

The modern method of hybrid seed production varies in different areas of the United States, but generally it is as follows. Plant breeders and geneticists at the State Experiment Stations and the Bureau of Plant Industry produce the inbreds. These are released to the seed trade after extensive

* In vegetative cells of flowering plants the chromosomes are *in pairs*. Thus genes located at similar positions on them are also in pairs. Genes of a gene-pair may have similar (*homozygous*) or opposite (*heterozygous*) action to each other, rather as crystals of lactic acid prepared in different ways rotate polarised light in different directions.

testing. The seed companies then produce two kinds of single-cross seed, *viz.* $(A \times B)$ and $(C \times D)$. Here *A*, *B*, *C* and *D* represent four different inbreds. Two rows of inbred *A* (the seed parent) are sown to one row of *B* which is to provide the pollen. When the male inflorescences (the *tassels*) on *A* start appearing, gangs go down the rows pulling them off, the process being known as *de-tasselling*. Thus only *B* pollen is available and all mature seed on *A* plants are $(A \times B)$ in genetic constitution. Similarly, crosses of $(C \times D)$ are made in separate, isolated fields. The two single-crosses are then ready for further hybridising.

Seed saved from the de-tasselled plants is sown the following year, using $(A \times B)$ seed for the new mother plants, and $(C \times D)$ seed for the pollen-producing plants. Both are, of course, vigorous hybrids, so that four or five rows of $(A \times B)$ can be planted to one of $(C \times D)$. Comparatively much larger amounts of pollen are available than with the inbreds. As the plants are very tall, it is often necessary for the gangs to de-tassel the $(A \times B)$ plants on horseback or on stilts.

Pollen from the $(C \times D)$ plants only is available for pollination so that mature seed on the $(A \times B)$ plants is now double-cross in constitution, i.e. $[(A \times B) \times (C \times D)]$. This is the seed which the seedsman sells to farmers as hybrid corn seed. It will be realised that the quantity produced by the single-cross hybrids far outstrips that produced by the original inbreds.

The table supplies an answer to those who want proof positive as to how hybrid corn has improved farmers' yields. For example, farmers in Iowa, where most of the land is put down to grain corn, now obtain an additional yield of about twenty bushels per acre to what they obtained fifteen years ago. The financial return for this far outstrips the extra price they pay for the hybrid seed. Farmers are generally conservative when it comes to trying out new varieties, and their rapid switch-over in ten years to the new type of seed is sufficient evidence of its great value. It has more than repaid the money spent on researches in hybrid vigour.

Although many species of cultivated plants show hybrid vigour of varying degrees, the basis of its commercial application is "Will it pay?". For instance, M. B. Crane and A. G. Brown have studied hybrid vigour in tomato crosses, using English varieties, and have found some combinations with good hybrid vigour. But *emasculation* (removal of the stamens), is a tedious operation; it is, above all, time-consuming. Hence, hybrid tomato seed is comparatively expensive to produce. The price of the seed is therefore high, and it is up to the farmer to decide whether it is worth paying the extra money. He must be sure that the higher price he pays for hybrid seed is compensated for by higher yields from the hybrids. Economics is inevitably the ruling factor in the application of hybrid vigour.

Again, in England some growers of, for example, cabbages and cauliflowers prefer a somewhat uneven crop as they do not wish to pick it all at the same time. It may pay them to spread the harvest so as to obtain best market prices. Besides economic factors influencing the utilisation of hybrid vigour, there are also those of a purely mechanical nature. Maize, which is primarily an American crop, has the advantage that male and female flowers are spatially separated on the same plant. This is not so with some of the crops which have hybrid possibilities in England.

Year	*Average yield for harvested acre, in Bushels*	*Percentage of land planted with hybrid corn*
1930	34	0
1931	33	0
1932	43	0
1933	40	0
1934	23*	2%
1935	38	7%
1936	18*	16%
1937	45	30%
1938	46	51%
1939	52	72%
1940	53	90%
1941	51	96%
1942	60	99%
1943	57	100%
1944	54	100%

* Short-crop years.

MAIZE YIELDS IN IOWA. This table shows the increased yields of grain due to increased use of hybrid maize seed. (*Data based on U.S.D.A. and G. F. Sprague.*)

Yet even formidable drawbacks such as difficulties in emasculation can be overcome. For instance, in America H. A. Jones and G. N. Davis have produced hybrid onion seed by using male-sterile lines which can be maintained vegetatively. As these produce no pollen, they may be inter-planted with pollen-producing onion inbreds. All their seed will be hybrid and no special labour has been involved. This, clearly, could be studied in England. Similarly D. Stewart and G. H. Coons, also in America, have overcome the difficulty of producing hybrid sugar beet seed by use of male-sterile lines that are controlled by the cytoplasm instead of by the chromosomes, as with onions. This is another crop which plant breeders in England may well investigate for hybrid vigour.

Useful results have already been obtained in this country by Dr. D. Lewis with the raspberry. In his studies of growing raspberries from seed, in order to overcome virus disease of plants propagated from canes, he found that some crosses between established varieties and selected seedlings gave improved yields compared with a standard variety such as Norfolk Giant. Results from crossing inbred raspberries will be available later on.

With the gradual interest in applying genetical principles and general plant breeding practices to forest tree improvement, there is plenty of scope here for testing the applicability of hybrid vigour.

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This article, based on a Friday evening discourse to the Royal Institution, is continued from p. 59.

The World Power Situation

Professor F. E. SIMON, F.R.S.

REVIEWING the potential power sources, we start, of course, with *coal*. Is the present power shortage in this country due to the supplies of coal running out? This is certainly not so directly, because there are stores for at least a few hundred years or so at the present rate of consumption. Indirectly perhaps to a certain extent, since the seams which now have to be mined do not lend themselves so easily to mechanisation as do, for instance, those in American mines. The life of the miner is for this reason still harder here than in many other countries. The main reason for the falling off in our coal supplies, in spite of a growing demand, is the fact that we cannot induce people to become miners, so that their total numbers have fallen steadily over the last thirty years. There has been no compensating increase in output owing to the greater difficulties of mechanisation, and for other reasons. The whole situation has been made even more serious in European countries by the effects and after-effects of war. But from the point of view of available deposits there will be no reason at all to worry in the foreseeable future.

To extrapolate in more than the very vaguest terms over more than a few hundred years is in my opinion not profitable, as we neither know how our needs for power will change, nor what new developments will occur. Science and technology develop more or less exponentially with time—political interruptions excluded—and taking the coefficient from the last hundred years, to extrapolate over more than a hundred years, though interesting, is not very relevant.

I am, therefore, not greatly worried whether those prophets are right who speak of world coal supplies lasting for 2000 years—with present consumption figures—or those who estimate they will last 20,000 years. There will be enough for all, at least in a unified world, which we may hope we will not take longer than a few decades to achieve.

The position with regard to *oil* seems at first sight to be more serious. Many fields in America and elsewhere are now nearing exhaustion and most predictions give America oil for only about 20 years at the present rate of consumption. The largest stores so far known are those of the Middle East, but no one wants to rely on these for obvious reasons. Now motor cars and aeroplanes will for some time to come depend on liquid fuels owing to their high concentration of energy and ease of handling. But the outlook for them is not really grim. First there are large stores of natural gas in America—nearly as big as the oil stores—which can be converted into petrol. Then there are enormous stores—equivalent to a hundred times the known American resources of high-grade oil—hidden in the oil shales of America and other countries; finally, as long as coal exists petrol can always be produced by the progress of hydrogenation. It is true that the price of petrol may rise even more than that of coal, but that is not really anything to worry about.

In discussing alternative power sources we must not only consider the total amounts of power which could be derived from them but must keep in mind two other points:

(*a*) Can they alleviate our short-term power shortage?
(*b*) Could they compete with ordinary fuels even when there was no fuel shortage?

Power from Water and Wind

Thirty per cent of the sun's radiation falling on the earth is used for lifting water, but only a very small part indeed of this water arrives at such a position that it can be used for the generation of power. Water power is, of course, a highly convenient form of energy, and its main disadvantage is the great capital expenditure required for the plant. All countries with potential sources of water power are already developing them as quickly as permitted by their economies. But water power can never be the full answer to the world's power needs, in particular because it is too much localised.

About two per cent of the sun's radiation is converted into kinetic energy of the air, which thus represents a considerable store of energy. Wind-power is used in small installations at isolated positions with success. The necessity for large structures, however, makes it unsuitable for use in the large-scale production of power; moreover, the supply of wind is so irregular that we would be in a grim position indeed if forced to rely on it.

Tidal Power

Tidal power also represents a considerable store of energy, but only at a few places would utilisation be possible, and it certainly cannot replace coal to any great extent. The Severn Barrage scheme has been seriously considered in this country, and the estimate has been made that with a capital expenditure of 50 million pounds we could save annually about a million tons of coal. But with the same capital expenditure devoted to improving our heating appliances, twenty times as much coal could be saved. Tidal power is obviously, therefore, not an attractive proposition at the present time.

Another project which has received considerable publicity lately is a French suggestion that *temperature differences in the ocean* could be used. A plant for 3000 kilowatts is said to be under construction. However, the energy obtainable by this method is not sufficiently 'concentrated', and a plant, even for this relatively small output, would have to be of enormous size. Certainly no appreciable amounts of energy can be collected in this way.

The Sun's Radiation

All the power sources discussed so far, with the exception of tidal power, derive their energy from the sun. Why is so little effort put into attempts to utilise the sun's energy directly? First, let us consider the orders of magnitude.

Let us assume that we could retain one-tenth of the energy falling on the outer atmosphere after losses due to reflection, absorption (including bad weather), and the change of intensity due to the changing angle of incidence. Let us assume further that we can utilise 10% of the energy arriving in the converting mechanism. Then a total area of the size of Egypt would be sufficient to supply power for the whole world. This shows that the project certainly has great potentialities, but also that very large areas will have to be covered with the converting mechanisms; they must therefore be very simple and cheap. Most of the attempts so far have used large mirrors to concentrate the radiation on boilers and, of course, these have to be turned according to the direction of the incident sunlight. This kind of installation is much too expensive for large-scale use, though modern developments in mirrors of aluminium foil might change the picture.

A better solution would be the use of cheap photo-electric cells, which might have efficiencies of power conversion of the order of 5–10% and there is no reason why such cells should not be developed. Photo-chemical reactions have also to be considered. Perhaps the simplest solution would be to grow plants, and afterwards burn them under boilers; in this connection it is quite encouraging to see that even if we used cane sugar as a fuel the cost would be (at present prices) only about 10 times as high as that of coal. The difficulty in plantations of this kind is in the provision of an adequate supply of water, since so much is lost by evaporation from the plants. I understand, however, that plans are now being considered for the building of very cheap greenhouses from plastic material which would permit the circulation of a restricted amount of water within the system. This is also an interesting proposition for food production. Incidentally, attempts to use the power from the sun and to grow more food would naturally compete with each other, but the areas potentially available are so large that one need not fear a clash.

Direct power from the sun will certainly not be used on any large scale within, say, the next 50 years. However, it seems to be one of the most promising possibilities for the more distant future and may supersede fuels—either because these become exhausted, or even earlier because they involve such unpleasant occupations as mining. It is known that the Russians are very actively interested in this source of power and that a certain amount of work is also going on in America. Unfortunately, I do not think anything is being done in the British Commonwealth.

Atomic Power

The sun gets its energy from a radioactive reaction, the conversion of hydrogen to helium. The direct conversion does not take place, as in this reaction seven particles have to meet at the same time—a most improbable event. A very complicated cycle, the 'carbon cycle', gives the possibility of letting the reaction go faster, but nevertheless even at the temperature of the interior of the sun (25 million degrees) one cycle takes 5 million years—and we have not so much time as the sun to wait. One should not say 'never', but does it not look as if this reaction could be put to any direct use on the earth in the foreseeable future.

We all know that in the last few years we have discovered how to tap nuclear energy by means of uranium fission. This is a very much simpler process than the building up of helium from hydrogen but, of course, very much less of the material required is available. The 'piles' in which the process of nuclear fission is maintained in the form of a chain reaction have often been described and the fact that these piles were used during the war for the production of plutonium is well known. The energy is developed in the form of heat, and so far no *direct* way of utilising the nuclear energy is in view. We have seen that when we use the intermediary of heat then in order to get the power efficiently we have to use high temperatures. During the war there was no time for such developments, and the energy was simply run to waste; now, however, efforts are concentrated on this problem. Serious technical difficulties have to be overcome. There is no doubt that they will be overcome, even though it may be 10 or 20 years, or even longer, before a satisfactory machine is developed.

When this is achieved, how can this energy be used most advantageously? First, we have to realise that nuclear reactors have a certain minimum size, and if we start with ordinary uranium this is quite formidable. By using concentrated material the size can be considerably reduced, but we can never dispense with the very heavy radiation shields necessary for protection. This probably means that the main application of nuclear fuels will be for large power plants.

There has been much speculation about the cost of nuclear power, and you have no doubt heard a lot about

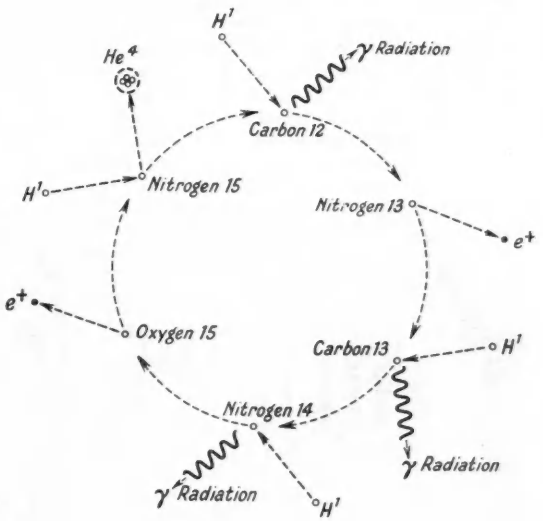


FIG. 6.—THE ENERGY PRODUCTION CYCLE IN THE SUN. If a hydrogen nucleus (H^1) collides with a carbon nucleus the former is captured, and short-wave gamma radiation (very short X-rays) is emitted. In the whole cycle responsible for the production of stellar energy, a series of such interactions takes place. The carbon nucleus takes up four hydrogen nuclei in turn, the consequent secondary changes leading to the emission of two positive electrons (positrons, denoted by e+) and three gamma rays. The final nucleus splits up to give a helium nucleus (He^4) and the original carbon nucleus. The latter thus acts as a carrier or catalyst in the conversion of hydrogen into helium.

the coming 'atomic age', when power will be had for the asking. However, the cost of fuel is less than one-sixth of what the consumer has to pay—the rest going to pay for generation, distribution and services. Thus, even if nuclear fuel costs nothing—and it certainly will not—we could not expect any spectacular changes.

Of course this argument cuts both ways: if nuclear fuel is much more expensive than coal, it will not affect the final price very considerably. Present estimates, which can only be very rough indeed, suggest that nuclear power might cost about the same as the power obtained from coal.

Nuclear power will certainly be most valuable for certain specialised purposes; obviously it will be a particularly attractive proposition for all purposes where the light weight of fuel is important, such as the propulsion of liners, or perhaps the irrigation of deserts.

However, the question of whether nuclear power will be able to satisfy an important proportion of our world power needs depends ultimately on the availability of the fissile materials. So far, uranium is absolutely essential and thorium can be used as an auxiliary fuel. Neither of these elements is actually very rare, but there are few deposits of really concentrated material. If we have to rely on the known deposits of this type, nuclear power will not be able to play an effective part in providing for the world's power needs.

The position may alter, however, if one of the two following possibilities is feasible. First, it may be possible to work up the deposits of very poor ores in a reasonably economic way. Secondly, it may be possible to use not only the uranium 235, but also the isotope 238 which is more than a hundred times as abundant as the 235. This depends on the number of new nuclei of plutonium which can be made (from 238 nuclei) per fission. If this figure is greater than unity one can, so to speak, 'breed' new fissile material and thus use up all the uranium. The chances of successful breeding are not yet known with certainty, but one thing is clear: even if it is possible, the building up of sufficiently large stores for any practical use will take a very long time, say 30–50 years.

Let us assume for purposes of argument that in one way or another we find enough fissile material to provide a large part of the world's power supplies. If the cost is roughly the same, what will be its advantages over coal? I have already mentioned the special attraction for some purposes which arises from the fact that only a very small amount of fuel is needed—particularly the reduced need for transport. Another advantage is that the unpleasantness of the mining operation itself may be largely avoided, although I should mention here that the situation may be different if we have to rely on poor ores, and from what one hears about large labour forces chasing after rather small amounts of ore in the mines in Saxony, it does not seem too promising.

But even if this were not so, we must not forget that an atomic energy plant is a singularly unpleasant type of plant, quite apart from the misuse to which the products can be put. It is true that in a normally running pile the radiation hazard can be made very small. The working parts of the plant, however, become highly radioactive, so that if some repair is needed one cannot approach the plant at once—it has to 'cool down', as it is called, for many months. Further, a very essential part of every atomic power plant is the chemical plant required to deal with the highly radioactive products; this is most difficult to work, since it can only be operated from a distance. Finally, a very tricky problem indeed is the question of disposal of the radioactive fission products. For a single pile, or even a few dozen, this would not be too difficult, but if any appreciable part of the world's power consumption had to be provided by atomic energy it would be a most serious problem.

Thus, summing up the prospects of atomic energy, one can say that it may prove very useful for some types of specialised projects. Whether it will ever be able to contribute an appreciable part of our total power remains to be seen, but this will certainly not happen within the next 50 years or so. Even then it will still have to compete with coal. With the present large effort going into the development of atomic energy, I believe at least some comparable effort should be devoted to improving the technical and social conditions in mining. For instance, one might argue that money spent on the development of underground gasification of coal would be just as likely to give good results in the relatively near future.

Once our conventional fuel supplies really begin to near exhaustion, atomic energy would probably find its most serious competitor in solar energy; it goes without saying that both of these power sources should be developed vigorously. But why the general public puts so much hope in atomic energy and, if I may say so, cold-shoulders the sun, I do not know—perhaps the sun has not quite the glamour of atomic energy. But after all, the sun is nothing else than a nuclear reactor and there is the definite advantage

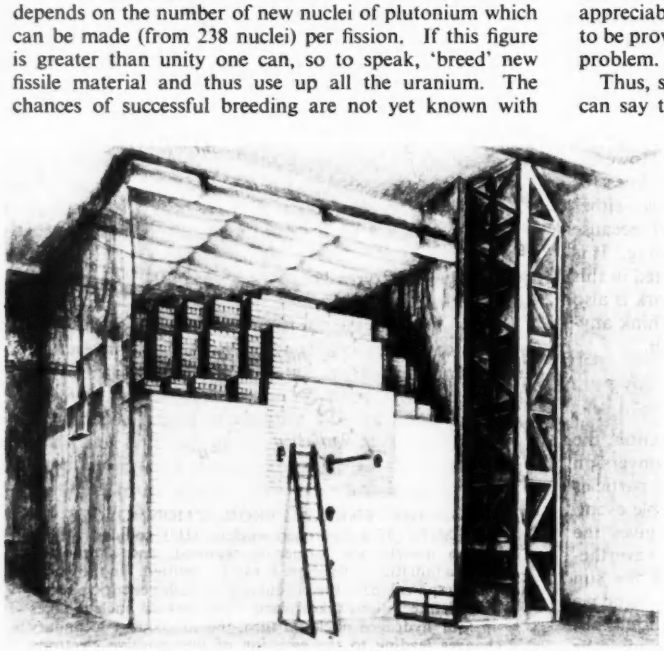


FIG. 7.—A sketch of the world's first atomic pile, which came into operation in December 1942. A quarter or half a century is likely to elapse before uranium replaces coal as a source of power to any considerable extent.

that it is at a safe distance, free for all, and out of reach of politicians.

Our Short-term Troubles

To sum up the position of our power resources: we need not worry about the more distant future. Even with enormously increased power consumption there are enough potential sources of power which can be made to yield their supplies. The sun's energy, and possibly atomic energy, will eventually be able to take over, but it would be irresponsible to count on either of these in the near future. Neither can any of the power sources which are already in practical use alleviate our short-term troubles.

The only way out is for us to stop throwing away our power as lavishly as we do at the present time. As I have already shown, we only utilise about one-thirtieth of the power consumed. To use an analogy, it is as if, being unable to pour milk out of a jug without spilling it, I had to empty a gallon jug in order to fill a small glass. I have a shrewd suspicion that my family would not let me get away with this, particularly when we are short of milk. The analogy actually goes a bit further. If we do not use the power properly, the rest has to go somewhere, either in the form of improperly utilised fuel, or smoke, which soils our towns and houses, or in the form of refuse which clogs up our machinery, or as heat which has to be removed from the working machinery—this latter is very often a limiting factor in design. In addition to this, of course, we have to transport and distribute these unnecessary amounts of fuel and energy.

Now in the case of power, the saving could not be quite as easily effected as in my analogy, but a very great deal could be done, certainly enough to save the relatively small amounts of fuel of which we are short. As you know, 20 or even 10 million tons of coal per year would make all the difference to this country.

The figure of 3% utilisation refers to the thermodynamic optimum, that is, only to fully reversible processes. Now of course no one expects to get anywhere near this; actually a fully reversible world would be a nightmare. Let us consider the two extreme cases, namely, very nearly irreversible and very nearly reversible processes. The first could be achieved with very simple machinery but at the expense of a prolific consumption of power; the second would mean very small power consumption but a very complicated machine; 'Kelvin' is much more complicated than 'Joule'. Or, imagine that you had no brakes on your motor car and had to rely on some mechanism to collect the energy when you wanted to decelerate. This last example shows clearly that friction is not the unmitigated nuisance most people think. Without friction we could move only on cogwheels, for instance, and if I now dropped something it would go on bouncing about for ever. On the other hand, we should not forget that improvements in technical developments have practically always been coupled with an increase in reversibility. The invention of the wheel was the first step towards reversibility and its full benefits could not be made use of until the Romans developed the hard road; much later, further improvement in reversibility came with the iron rail. Most of the benefits which the supply of electrical power gives us are again due to the fact that its distribution is very nearly reversible.

FIG. 8.—A Heat Pump. (*Courtesy, Escher Wyss Engineering Company.*)

Where the optimum lies will depend on many factors, technical, economical and psychological. The human body strikes a balance at an overall efficiency of about 25%. In power utilisation we can—by applying present knowledge only—increase our 3–4% utilisation to roughly 10%. I will mention a few items, the most important being in the field of heating and insulation of our houses. How coal itself should best be used is a rather complicated matter as we have to consider coke and gas also and the fact that coal is a source of valuable chemicals. But it is clear that we will have to abandon the open fireplace and irreversible electrical heating. The heat pump is not a very attractive proposition under our conditions, but a system based on the same principle—and in practice even more efficient—namely the use of 'back pressure turbines' in power stations, with utilisation of the 'off-steam' for district heating, should certainly be considered wherever permitted by the geographical conditions. Heat pumps in industry could save something, as could the electrification of our railways. In the home a number of small items, such as the use of fluorescent lighting or pressure cookers would add up to a quite appreciable saving. The extended use of plastics and powder metallurgy in industry would permit the fabrication of materials without the prolific power consumption of present methods.

Open Fires

Most of these improvements could of course only be put into operation gradually, say over the next twenty years, because of the capital investment needed. They would all gradually make themselves felt in bringing down our fuel consumption. There is, however, one way of effecting an

improvement quickly—by abolishing the open fireplace, which now costs us about 30 million tons of coal per year. I know I am treading on delicate ground, but one should not think of the fireplace from the point of view, say, of the fireplace in a college common room with enough 'scouts' to look after it. You must think of what goes on, say, in a suburb. Each of the houses will have a fireplace which not only heats it inefficiently but also pours out dirt both into the house and over the town in profusion, injuring the health of the people and adding to the housewife's troubles another, and quite unnecessary, job. I have already said that efficiency is not everything; nevertheless it is something and even if one has a sentimental attachment to open fireplaces the position has arisen where we simply cannot afford them. To use them is in many respects more wasteful than lighting cigarettes with spills made from £5 notes, as Russian grand dukes are said to have done.

Naturally there has been quite a lot of discussion on this matter. I have seen a letter written to a well-known economic journal, admitting at least some of the disadvantages of open fireplaces but maintaining that they were worth while from other points of view; in particular this letter emphasised that the fireplace acted as a source of inspiration. I do not want to stress the example of other countries, whose inhabitants after all are not without inspiration, but I have not noticed that people here have more good ideas in winter than in summer; thus, I venture to suggest that there must be other sources of inspiration available apart from the contemplation of the fluctuations of a household appliance.

The immediate abolition of open fires would, in my opinion, be the greatest and easiest step towards economic recovery. They could be replaced by simple stoves designed to fit into existing fireplaces. I believe the Government could not spend any money more profitably than by offering to provide and install such stoves free of charge. If only half the owners of fireplaces accepted this offer, about 10–15 million tons of coal could be saved each year at a capital expenditure which, if the enterprise were organised properly, could not be more than £30 million.

I have dwelt on this example at some length as it seems to me to be symptomatic of the whole situation. You know from the newspapers how anxiously the attainment of the coal target is watched and how the falling short of 2 or 3 million tons in the year is regarded as a very serious matter. A very modest effort would save that amount. Most people, however, prefer to stake their hopes on new sources of power—even such doubtful ones as atomic energy—before they will seriously consider changing their old squandering habits.

This love of squandering seems to be very deeply seated in humanity. It is not only the schoolboy who is enthusiastic about the noise and prolific production of steam and fumes of that most uneconomical machine, the locomotive. Adults are also impressed by, say, the noises produced by aeroplanes or the light effects of the blast furnace or Bessemer converter. Most articles on the wonderful achievements of technology include exclamations of admiration for just those things about which we should be most ashamed—while hardly anyone praises a machine which does its work quietly and efficiently. This subject would certainly be worth examining more closely, but that would lead me too far; I only want to add that there seems to be proportionality between the irreversible increase in entropy of some act and the pleasure it creates, and I have often been tempted to use this for a definition of a unit of pleasure.

I am now coming to the end of my lecture and I hope I have given you a balanced picture of the world power situation. I started by referring to the food shortage. We now see that it will be a much easier matter to do something quickly about the power shortage than about the food shortage. With relatively little effort—and without going short—we could save enough fuel to end our short-term troubles, and with a real effort fuel consumption could be cut by half. I am confident that with proper education of the public something worth while could be achieved in the near future. In both cases the critical period is the present and near future since supplies cannot be increased quickly, and as we know, the world food situation may even become catastrophic. All these problems are aggravated by political and international tension.

However, there are potentially enough sources of both food and power to satisfy the present world population even without atomic energy. With the possibility of future developments such as the synthesis of food or the use of solar power it is not very likely that shortage of either power or food will set the limit to the growth of the world's population for a long time to come—though whether such a growth is desirable is, of course, quite another question.

Atomic Control without Russia

THE recent DISCOVERY article by E. M. Friedwald on the subject of atomic energy control created very widespread interest, and have been extensively quoted all over the world. There has been considerable support for his proposal that the time has come to organise a system of atomic energy control apart from the Russian bloc. Last month Sir James Chadwick, who was the top British scientist on the atom bomb project, came out in favour of the Friedwald scheme. Addressing the Cambridge University Society for International Affairs he said that if the prospect of world-wide control of atomic energy had gone or, at any rate, receded, a practicable alternative was informal co-operation between the governments that were concerned with development of the atomic bomb—the United States, Great Britain, and Canada, together possibly with some other members of the British Commonwealth. "This implies working under the general leadership of the United States, which is still the sole possessor of the atomic bomb and the enormous facilities required in its production," he said. "Leadership must be where the power is, and for the present and some time to come it is with the United States. The closer association of the Dominions with this country and the development of the resources of the British Commonwealth will, of course, make us a stronger and more useful ally and give us a greater share in international affairs, but at present we are not in a position to replace the United States."

Tasting and Smelling

GEOFFREY H. BOURNE, D.Phil., D.Sc.

MAN is said to have five senses, although he really has six, the sixth being the *proprioceptive* sense, the sense of muscular position. Of these senses two—*taste* and *smell*—can be described as being chemical in nature; that is, the substance to be smelled or tasted must be brought into physical contact with the appropriate regions of the body. In the case of other senses, such as sight and hearing, the stimulus is conveyed by waves or pulses of energy. Recently an American worker has claimed that smelling is also a process of detection of waves of energy; he says that odoriferous particles give off infra-red waves which can be detected by the smelling cells in the nose. However, this view is by no means accepted, and must in fact be regarded with extreme scepticism until convincing proof is offered of the hypothesis.

Since the senses of smelling and tasting are probably chemical in nature, they can be traced back to their origin as a general vague chemical sense possessed by simple undifferentiated animals. Protozoa (unicellular animals) such as *Amoeba* and *Paramoecium* have a general chemical sensitivity, probably over the whole of their single-celled bodies, although it is possible that the end of the *Paramoecium* which normally goes first when the animal moves, is more sensitive than the other parts of the animal. If you put a minute droplet of dilute acid into a drop of water containing *Amoebae* or *Paramoecia* they can be observed immediately to move away from it. However, the range of chemical substances to which they react is not great. Odoriferous substances as such do not seem to have a very great effect but the maximum reaction is given to those substances most likely to damage the thin cell wall of their unicellular bodies.

The multicellular animals of the jelly-fish type display a similar type of reaction to chemical substances, and even relatively complex animals such as the earthworm have not advanced very far beyond this in chemical discrimination. Higher animals, both vertebrates and invertebrates, have both smell and taste senses although the latter often have them located in very unusual sites. For example, animals such as squids have taste organs in their tentacles, some insects have them in their feet. Some animals, e.g. the flatworm, appear to have taste sensation spread all over the body. Insects also have extremely sensitive organs for registering smell; for example, some beetles can detect the odour of skatol when it is diluted 100,000 times. More incredible is the keenness of the scent of the male moth for the female moth. One experiment has been described where one female moth collected round herself in a few hours no fewer than 125 males, which must have come from many miles away, and the dilution of the odour which attracted them must have been immeasurable. Such cases as this incline one to think that at least in insects the apparent sense of smell may in fact be really ability to detect a minute amount of some sort of radiation.

The lowest vertebrates (e.g. fish), appear to have both tasting and smelling organs although, since the smelling organ is normally filled with sea-water in which the substances smelled are dissolved, it is hard to conceive of any significant difference between them. Fish do not have their taste organs restricted to the mouth as do mammals, but may have them scattered on various parts of the body, and very large numbers of these external taste organs are present in deep-sea fishes. Taste receptors may be present on the pectoral fins, or on the head; the lateral line (easily seen in most fish) which runs down the side of the body, has in it a number of organs which under the microscope are very similar to taste-buds. In fact if a piece of meat, or a piece of material soaked in meat juice, is held near the side of a catfish, for instance, it will turn and snap at it, the presence of the meaty taste having no doubt been conveyed to the fish's brain as a result of the stimulation of the taste buds in its flank. The long tentacle-like 'barbels' of the catfish also have taste organs on them.

It has been mentioned that there does not appear to be much difference between smelling and tasting for fish, but such a difference must, in fact, exist, because experiments have been carried out in which the part of the brain receiving the nerves of smell was severed from the rest of the brain in a dogfish. The animal though hungry and though in sight of food, and with functioning taste organs, made no effort to feed. From this experiment it was obvious that the dogfish finds its food almost entirely by smell and that smell in these animals may in fact be different from taste. In animals such as birds the chemical senses appear to be much reduced. Birds, it is said, have very few taste organs in their mouths and seem to have little ability to discriminate between various types of taste. Sight, which reaches a very high degree of development in these animals, is much more important to them than the sense of smell.

Living in a World of Smell

The reverse is the case in the lower mammals; one's dog, for example, lives in a world of smells. Odours of various sorts convey to it far more than they convey to human beings. The evolution of man from lower mammals has in fact been one of gradual reduction of size and of the importance of that part of the brain which deals with interpretation of smell and its replacement by those parts concerned with hearing and, particularly, sight. Obviously a world of smells can only be a vague and shadowy one, and the information obtained must be much less precise than that obtained from sight.

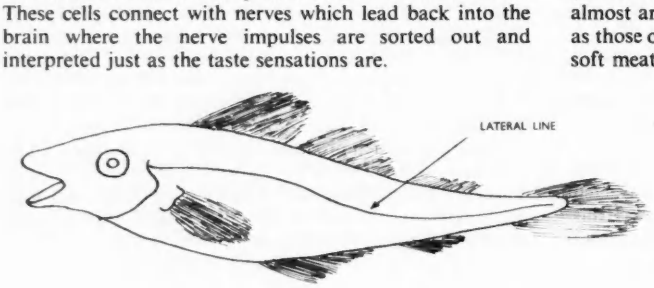
The organs which produce the sensations which we know as taste and smell have a very special structure. Taste is registered by *taste buds*. In man they are distributed over the tongue and the soft palate; altogether there are something like 9000 to 10,000 of them. The pig and goat have about 14,000 to 15,000, the rabbit 17,000 and the ox about 35,000, so presumably the sense of taste in these animals is more acute than in ourselves. In children taste buds are more widely distributed in the mouth, and they may be

found on the inside of cheeks as well. The taste buds appear to be particularly located in the folds of the skin on the surface of the tongue, which are called *papillae*. On the sides of the papillae the taste buds may be easily recognised under the microscope. They consist of little pits with a narrow opening called the 'gustatory pore'. Inside this little pit are two types of thin narrow cells with one end directed towards the 'pore'. The cells of one group—the 'gustatory cells', have a little hair-like process at the tip called a 'gustatory hair', and this projects through the gustatory pore and is presumably the sensitive part of the taste-bud. The other group of cells are thought to be supporting in function, but it is quite possible that they, too, play some part in the mechanism of tasting.

Four Chief Tastes

Different parts of the tongue appear to be particularly sensitive to different types of taste. For example, the sour taste is located about the middle of the sides of the tongue and salty taste is on the sides towards the tip. Sweet taste is mostly located at the tip itself and bitter mostly at the back. This shows that there is a physiological explanation why wines should be sipped, and beer 'tossed off'. Both the tip and the back of the tongue are in fact sensitive to all four tastes, though they are more sensitive to sweet and bitter tastes respectively than to others. From the 'gustatory cells' nerve messages initiated by the effect of the taste substance on the cell, pass by means of nerves (which connect with the taste buds) to the brain where they are subject to analysis and interpretation by the cells of the brain.

The sense of taste is said to be similar in many respects to the sense of smell—certainly the types of cell concerned with both processes resemble one another in general structure. The whole of the inside of the nose is lined by a soft moist skin called a *mucous membrane*. Only a relatively small area of this is used for smelling. This area of mucous membrane is called the 'olfactory region' and it is situated at the top of, and fairly well back in, the nasal cavity. There are two sorts of cells in the mucous membrane in this region. One sort is said to be supporting in function and the cells of the other type have at one end, not a single hair-like process as in the tasting cells, but a little bunch of hairs which come out on to the surface of the mucous membrane. It is these hairs which are thought to be the sensitive part of the olfactory mucous membrane, which reacts with the odoriferous substances to produce the sensation of smell. These cells connect with nerves which lead back into the brain where the nerve impulses are sorted out and interpreted just as the taste sensations are.



Outline of fish. The lateral line is made up of a number of organs which resemble taste-buds.

As indicated above, there appear to be four chief tastes —*sweet, sour, salty* and *bitter*. The tongue, in addition, is sensitive to touch (which enables it to appreciate *texture* in food), and to *heat* and *cold*.

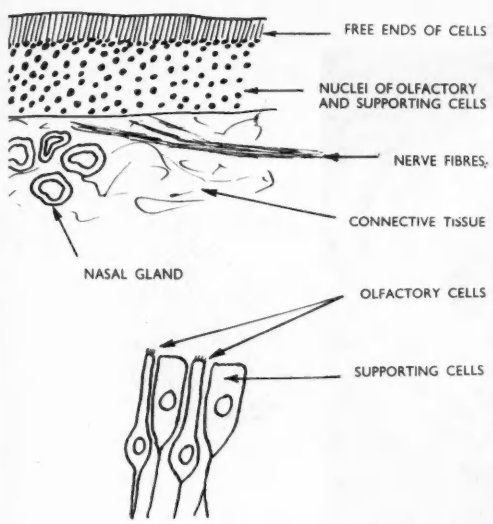
In addition much of what is called taste is really *odour*. The vapours of substances being eaten ascend into the back of the nose from the mouth and stimulate the olfactory cells there. What we call taste is therefore a complex experience which is really the result of tasting, texture and temperature of food, and smelling. In fact, if the nose is held when eating or drinking so that the vapours pass only with difficulty in to the nose, the food or drink taste very flat.

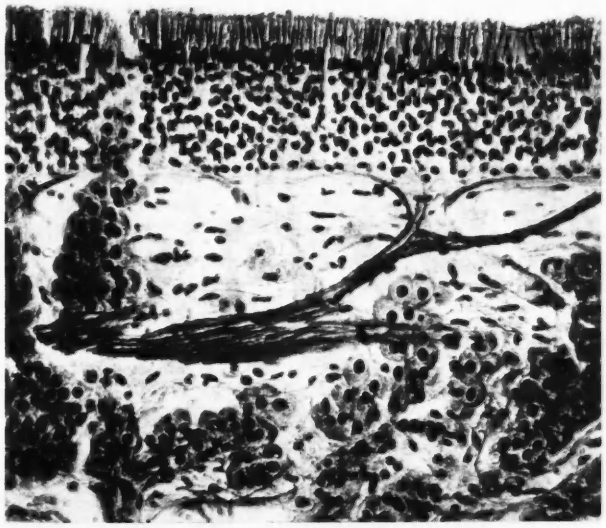
In addition to the various factors involved in taste, we have the hot and cold tastes induced by such substances as pepper and ginger and menthol. Some scientists say that these substances have this effect because they stimulate those parts of the tongue which are sensitive to hot and cold temperatures, others believe they affect the bare nerve endings in the skin of the tongue and mouth which are sensitive to pain and also show general sensitivity to chemical substances. Temperature actually has a most profound effect on the taste of various substances. Most meats and vegetables have a more attractive and a stronger flavour when they are served hot. Iced coffee must be very much stronger than hot coffee if it is to be appreciated and it must have very much more sugar in it to taste sweet. Quinine tastes less bitter and castor oil less revolting if a piece of ice is sucked for a few minutes before they are taken.

'Synthetic' Tastes

Attempts to show that substances of a particular chemical structure have some similarity of taste have proved quite unsuccessful. Three sweet-tasting substances which are well known to most people are sugar, glycerine, and saccharine and yet they are widely different in chemical constitution. Lead acetate also has a sweet taste and it is quite different in chemical nature from the aforementioned substances. It was once used, with disastrous results, because it is poisonous, as a sweetening agent in confectionery. Similarly, bitter-tasting substances vary widely in chemical constitution. Some scientists believe that all tastes are compounded of the four main or basic tastes in various proportions and it has been claimed that by mixing suitable proportions of common salt (sodium chloride), quinine, tartaric acid and glucose that almost any taste could be imitated. However, tastes such as those of the salts of glutamic acid, which have a pleasant soft meaty taste cannot be imitated in this way. Alkaline substances are also distinctive, and other substances such as tannin have an astringent taste. There is also a 'metallic' taste which is quite different from anything else. Nevertheless, there is no doubt that different proportions of the basic taste do account partly for the taste of many things but in addition one must take into account, at least, temperature, texture, and smell.

The phenomenon of taste is therefore not a simple or a single process but is a compound of several different sensations.





(*Left*).—Diagram of the olfactory membrane.
(*Right*).—Photomicrograph of section through olfactory membrane.

The flavour we ascribe mentally to a food after tasting is partly psychological, that is to say, it is a product of the mind. The examples will illustrate this. One usually associates a lime or lemon flavouring with something coloured green, orange flavour with anything coloured yellowy-red, a lemon flavour with yellow and a raspberry flavour with red. Jelly sweets were made up by one experimenter in which say, lemon flavour was put into a red jelly, raspberry flavour into green jellies and so on. Experimental subjects who knew nothing of the tricks which were about to be played on them found great difficulty in giving the correct flavours of these sweets, their interpretation of the taste impulses being greatly confused by the variation of the colouring.

In another experiment small jellies instead of being sweetened and flavoured to simulate fruits were flavoured with varying strengths of onion. Of a number of young ladies who unsuspectingly agreed to try these concoctions, two had vomiting attacks afterwards. They were able to distinguish the onion flavour all right, but they had mentally prepared themselves for a particular type of taste on seeing the jellies and the mental shock of receiving an onion taste instead caused the vomiting.

Flavours perform a useful physiological function because an agreeable flavour provokes a plentiful supply of saliva which aids in digestion and mastication and it causes secretion of gastric juice which aids subsequent digestion.

There appears to be less justification for claiming that odours are compounded of a few basic smells than there is for making an analogous claim for taste. Attempts have been made to classify odours. Zwaademaker did this in 1895 as follows:

Ethereal	Examples:	Fruits
Aromatic	,,	Camphor, cloves
Balsamic	,,	Flowers, vanillin
Ambrosial	,,	Musk
Alliaceous	,,	Chlorine, sulphuretted hydrogen. Benzine
Empyreumatic	Examples:	Roasted coffee
Capryllic	,,	Cheese
Repulsive	,,	Bed-bug
Nauseating or foetid	,,	Faeces

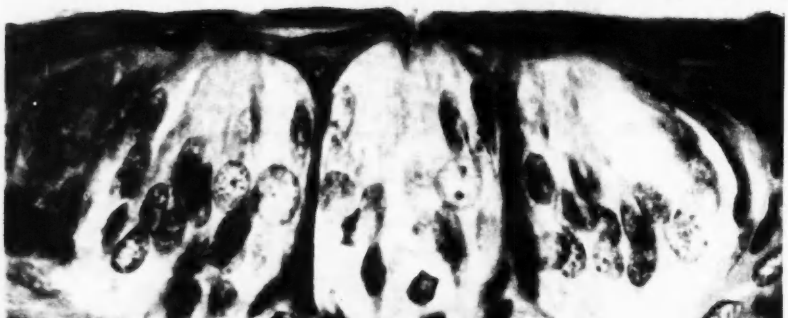
Other scientists have tried to simplify this classification by reducing the primary smell groups to six, e.g.:

1. Spicy
2. Flowery
3. Fruity
4. Resinous
5. Burnt
6. Foul

All smells, it is claimed by these authors, are really the expression of various combinations of these basic odours. Odours apparently have no relation to the chemical constitution of various substances. Even chemical compounds which have a mirror image chemical structure may have different odours, and substances which differ very considerably in chemical constitution may have very similar odours.

Bloodhounds and Criminals

The taste and smell of different substances cannot in fact fit into any particular pattern of chemical constitution and as a result any reasonable explanation of how the brain distinguishes one type of smell or taste from another is still very obscure. Substances, before they can be smelled or tasted, must pass through the thin membranes on the olfactory or gustatory hairs and on their ability to do so the nature of their smell or taste may depend. The writer has shown that an enzyme called alkaline phosphatase is present in fairly high concentrations in taste buds and nasal mucosa, so perhaps the effect of various substances on this enzyme has something to do with their taste or smell. Even if we understood how a substance affected the taste or smelling cells we would still have to find out how the brain interprets the messages it receives. Professor E. D. Adrian has pointed out that to a bloodhound each new



Photomicrograph of section through tongue, showing three taste-buds.

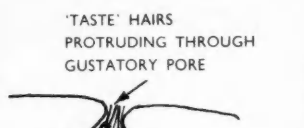


Diagram showing structure of taste-bud.

criminal has a smell of his own and there cannot be special nerve endings in the smelling part of the animal's nose for each criminal. The messages coming from the nose must, however, vary in some way. Professor Adrian has described experiments in which the skull of an animal has been opened under an anaesthetic and electrodes put into the nerve fibres carrying the smell pulses to the brain. So far as we know the nerve impulses which come to the brain from the eye and ear, the mouth and the nose are more or less the same and it is the brain which interprets them as sight, sound, taste, and smell. Presumably if it were possible by operation to cross over these connexions one would be able to taste a symphony concert and smell a painting, to hear lightning and see thunder.

If the fine electric currents produced in the electrode mentioned above by the passage of a nerve impulse are amplified, one can hear the effects of stimulating the nose. Merely breathing clean odourless air through the nose appears to stimulate the olfactory cells and nerve impulses pass to the brain from them. This is a mechanical effect. In man some of the olfactory cells are readily accessible to vapours passing through the nose but some are less accessible and presumably only react with substances which are so diffusible that they can get through quickly to the cells. It is possible that some of these smelling cells are more sensitive to one sort of odour than to another. Professor Hill describes the electrical responses to smells as follows: "When a particular smell reaches the olfactory organ, therefore, the receptors will come in at different rates and different times according no doubt to their chemical affinities, but also to their position on the olfactory surface. One after another will come in like the different instruments of an orchestra, and just as the ear can recognise all the fine shades of a chord built up progressively, so the nose may be able to distinguish the nature of the smell from the evolution of the discharge in the different nerve fibres." It seems very likely that it is by some mechanism such as this that the brain is able to interpret smells, and possibly taste may be explained in a somewhat similar way.

We are still a long way, however, from a complete understanding of the physiology of these two senses, but there seems every hope that with new methods of attack our knowledge may soon make a sudden advance in this direction.

THE COMMONSENSE OF RELATIVITY—*Contd. from page 76.*

in that position—we cannot yet think naturally and intuitively in Einsteinian terms. But inexorably—and in time—our 'commonsense' will be forced to adjust itself. No doubt in another generation or two men will have become so used to thinking in Einsteinian terms that they will have come to believe that the properties of Einstein's universe are intuitively obvious. And then the next major revolution in physics will be attacked as contrary to Einsteinian 'commonsense'.

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Far and Near

Darwin on Government Science

AT the annual meeting of the Parliamentary and Scientific Committee, which is the main link between science and politicians in Britain, SIR CHARLES DARWIN made some trenchant comments about conditions in the Scientific Civil Service. He said that today it provides careers that stand quite favourable comparison with most others open to scientists.

"The pay is of course inadequate—have you ever met anyone who admitted his pay was adequate—but in a general way it compares fairly well with the main competing professions of the university and industry," Sir Charles said. "At the moment we are suffering in recruitment because the starting pay is a bit lower than in industry; later, it beats it on the average, but young men of 24 are not apt to consider the merits of pension schemes and of fairly slow increments of salary, partly because any young man worth his salt is sure he will get to the top much faster than these calculable advances imply. At the top, too, there is of course a great discrepancy, for no large organisation like the Service can ever hope to give salaries on the level that industry awards to its leaders—but to only rather few of them. When you compare our state with that of the universities, the comparison is rather more level; I should say on the whole our pay is a bit higher, but we have to work very much harder for it—my university friends do not admit this last point, but I have myself been in both camps, and I claim to know. Apart from this we suffer inevitably from some of the rigidity which is unavoidable in a really large organisation—I suppose we spend a good part of our time regarding as enemies of the human race, those professional sayers of "No", our Establishment Officers, and behind them the Treasury—but in my calmer moments, when I look at what is required of them, my heart melts for these poor outcasts, and I frankly acknowledge they do a difficult job very well."

"There is one small but important feature we have which seems to me to mitigate the rigidity of the Civil Service in a very essential way," he continued. "This is the arrangements for a limited number of special promotions given for scientific merit—there must by now be over 40 senior principal scientific officers, who would not have been promoted in the ordinary scheme, because there were no vacancies in the higher grade. They are really a rather distinguished lot. In all cases we promoted them on the ground that they were doing work well above the level implied by their duties, and many of them have said they preferred their present work and would refuse promotion if it involved taking on more administrative duties. These brevet ranks are a most valuable feature of the Scientific Civil Service."

"I cannot omit mentioning another aspect where the future has a gloomy outlook. At every point, we—I fancy in common with every other employer—foresee great danger in the terrible shortage of recruits for our staff, in particular our higher staff. Not long ago I was looking at a paper I had prepared in 1942 retailing the plannings that were to be made for the brave new world when the war should be over. There were quite a lot of things, many of which have since been done; but when I came to the last paragraph it almost made me laugh, though very much on the wrong side of my mouth. I had been instructed to say how far we could help in mitigating the terrible unemployment which would arise on the demobilisation of enormous numbers of scientists."

"Well, unlike the Service Departments, during the war we could not get many recruits—rather the contrary, and then we found that when it was over we still got hardly any, and so there is a shortage in our staffs between the ages of say 30 and 45, which threatens trouble ten or fifteen years hence. The shortage also makes it hard to do justice to the few younger recruits we are now getting, for we should like to arrange things so that they could broaden their knowledge and skills, but there is such a demand for work, that it is not possible to risk the loss of working time that is inevitable when a man has to learn a new job. The fact of the matter is that an institution like ours is like an army, and like an army it must have reserve troops if it is to win victories. Since the war we have not managed to build up our reserves at all, and at the present time, what with production drives and so on, we are being absolutely continuously required to have all our troops in the front line. It was bad enough to be like this for the six years of war, but to have no reserves for ten years on end threatens to be a calamity."

Pacific Science Congress

ABOUT 120 scientists from more than fifteen countries took part in the Seventh Pacific Science Congress, held at Auckland, New Zealand, last month. A transportation grant of $20,000 given by Unesco to the Congress made it possible for many scientists from countries bordering on the Pacific as well as from Norway, Holland and France to attend the meeting. The last Pacific Science Congress took place in San Francisco in 1939. Dr. Wang Ghing-Hsi, Head of the Division of Pure Sciences of Unesco, attended as the Unesco representative.

Gold Medal for David Lack

THE Brewster Gold Medal given annually by the American Ornithologists Union to the author of the most important work relating to the birds of the Western Hemisphere published during the preceding six years, has been awarded to David Lack for his book *Darwin's Finches*, published in 1947 by the Cambridge University Press. We considered this book of special importance (because of the light it shed on the mechanism of evolution) and devoted a full-length article to it in the June 1947 issue of DISCOVERY (pp. 174–6).

Orders for binding cases for Volume IX of DISCOVERY *can now be accepted for delivery next month, price* 4*s. post free. We shall be pleased to bind readers' copies, supplying index, title-page and binding case, at an inclusive charge of* 9*s.* 6*d. Bound volumes for* 1948 *are also available, Price* 30*s.*

Underground Gasification: Gas-turbine Experiments in Alabama

PRELIMINARY arrangements are progressing for the second field experiment in the U.S.A. in underground gasification of coal, and the project will acquire additional significance because of the use of a gas turbine in the studies, reports *The Chemical Age*. The Bureau of Mines, which in collaboration with the Alabama Power Company is conducting research on a 300-acre tract near Gorgas, Alabama, have shipped to the site a gas turbine with a 23,000 cu. ft.-per-minute compressor capacity. It is intended to use it experimentally in burning the gaseous mixture from the combustion of coal at 60 to 100 ft. below the surface.

The first experiment with underground gasification was completed in the winter of 1946–7 by a similar Government-sponsored joint project of the Bureau of Mines and the Alabama Power Company. The present experiment entails more elaborate engineering preparations. This time, air will be blown underground to support controlled combustion in the coal seam. If the resultant fuel gas burns well in the gas-turbine power plant, it will establish the possibility of locating gas-turbine electric power plants where coal exists and transmitting the output to urban industrial markets.

'Star House' for London

IN April 1946 we advocated the establishment of at least one planetarium in Britain, a need made particularly obvious by the fact that nearly every other country in Europe has its planetarium. Now the Ministry of Education has announced that a planetarium will be established at the Science Museum, S. Kensington.

The director of the Museum has been to the United States to inspect their 'star houses', and he hopes to acquire an American-made planetarium for installation when the Science Museum's new building has been completed—which will be about 1951.

S.I.M.A. Social Function

THE Scientific Instrument Manufacturers' Association will hold their Annual Dinner-Dance at the Mayfair Hotel on May 6, 1949, during the run of the British Industries Fair. Further information can be obtained from the Secretary at the Association's Headquarters, at 26, Russell Square, London, W.C.1.

Croonian Lecture by an American

THIS year's Croonian Lecture to the Royal Society will be delivered on June 30 by Dr. D. W. Bronk, Foreign Member R.S., Foreign Secretary of the National Academy of Sciences, and Chairman of the National Research Council of the United States. As Director of the Johnson Institute for Medical Physics in the University of Pennsylvania he has greatly influenced the development of biophysics in the United States, his special field of work being the physiology of the nervous system. His most recent work has been on the oxygen consumption of the brain.

The Bakerian Lecture for 1949 will be delivered on May 12 by Professor Sir Harold Raistrick, F.R.S., Professor of Biochemistry at London University.

Wilkins Lecturer for 1949 will be Professor E. N. da C. Andrade, F.R.S.

Medicine at British Council

DR. MARGARET SUTTILL, M.B., B.S., who has been on the staff of the British Council since May 1945 has been appointed Director of the Medical Department in succession to DR. G. A. W. ANGUS.

A Lighter, Safer, Fireman's Helmet

A PLASTIC fireman's helmet has been designed and may be adopted soon. It is made of woven glass fabric impregnated with a synthetic resin and is considerably better than the helmets now in use. It combines lightness and safety with comfort and smartness. The new helmet is the result of research by the D.S.I.R. and Fire Offices' Committee Joint Fire Research Organisation. Most present helmets are made of either leather or cork and their design springs from the old brass helmet, each one being a complicated piece of construction which can be done only by specially trained workers. The new helmet would be particularly useful as it can protect the wearer against high-voltage electricity.

Michurin's Technique takes the Prize

THE Timiryazev Prize awarded annually by the U.S.S.R. Academy of Sciences has gone to PROFESSOR PAUL DENKEL for his work in increasing the drought-resisting power of plants. Professor Denkel's method consists in what he calls presowing conditioning.

While still in the seed, plants are conditioned for scarcity of moisture, and this, it is claimed, enables them to stand up better against drought and contain moisture in themselves longer when the amount of it in the soil and atmosphere is inadequate. The method is reported as already in use in the dry regions of Western Siberia and yields bigger than normal by 15–40% are claimed. "My work is fresh proof," says Professor Denkel, "that by applying to science evolved by Michurin man can change the nature of plants."

Death of Wheat Expert

PROFESSOR JOHN PERCIVAL, author of the now classic book, *The Wheat Plant*, died at Mortimer, Berkshire, last month. He was Professor of Botany at the Wye Agricultural College from 1894 to 1903, and then Professor of Agricultural Botany at Reading (1903–32). His *Agricultural Botany* (first published in 1900) became a standard text-book.

Science Writers honour Blackett

GUEST of honour at the annual dinner of the Association of British Science Writers, held in London on March 22, was PROFESSOR P. M. S. BLACKETT, who was recently made Dean of the Faculty of Science at Manchester University.

The A.Sc.W. Economises

FACED with a declining membership and rising expenses, the Association of Scientific Workers (the scientists' trade union which is affiliated to the T.U.C. and World Federation of Trade Unions) has launched an economy drive. The aim is to reduce expenditure by £1,500 p.a., and the organising staff is being reduced accordingly.

MR. ROY INNES, General Secretary since 1945, leaves on March 31st and is replaced by MR. TED AINLEY. Hitherto there have been two Organisers for the Southern Region; henceforward there will be only one—MR. J. K. DUTTON.

It is expected that these changes will save about £1,000. Another economy measure involves the reduction of meetings held by the Executive Committee from twelve a year to seven. This step will result in some loss of democratic control within the Association, the particular feature on which the A.Sc.W. has always prided itself. There is liable to be considerable opposition to this sacrifice, especially in Scotland, where there has long been talk of the need for an autonomous Scottish Association for scientific workers.

Science in Germany

THE latest issue of the A.Sc.W. (*Scientific Worker*, February 1949) contains a revealing article on German science in which DR. R. C. MURRAY suggests that something approaching the pre-war Nazi organisation of scientists is being revived in the British and American zones. Last year a delegation comprising SIR ROBERT WATSON-WATT, J. G. CROWTHER and DR. MURRAY spent twelve days visiting German scientific institutions.

Dr. Murray maintains that German science on the pre-war pattern with its dangerous attachment to the State is being revived, and he implies that the Max Planck Society for the Advancement of Science and Learning is identical in every way—particularly in its aims—with the old Kaiser Wilhelm Gesellschaft. Says Dr. Murray, "Does this Society dedicate itself to the task of 'seeing that science is placed at the disposal of mankind for the service of peace and civilisation'? Precisely the reverse. It is an 'Association of independent research institutes, neither belonging to the State nor to industry'. It carries on scientific research in absolute freedom and independence, without any obligation to orders, subject only to law. The arrangements for self-government of the society contained in the statutes are extremely undemocratic, and ensure that the management will remain in the hands of a small group of elder scientists or those of whose ideas they entirely approve. If this constitution is more democratic than that of the Kaiser Wilhelm Gesellschaft that body must indeed have been authoritarian. 'Back to the *status quo*' is the sum total of the social philosophy of the average German scientist."

Dr. Murray asserts that the independence of any German research institute is in practice mythical, because it must accept money from industry, which "in the British Zone remains largely in private or semi-private hands, and German industrialists are not noted for socially progressive ideas".

Referring to the I.G. Farbenindustrie, Dr. Murray says that the organisation of research in the factories at Leverkusen and Elberfeld seems to be substantially the same as before the war. There is no doubt, says Dr. Murray, that Dr. Bayer, the Research Director and son of the founder of this branch of the cartel, is in charge of research as before even though the firm is nominally in dissolution. The Control Commission staff consider (according to Dr. Murray) that all leading Germans with whom they come into contact are as nationalist in sentiment as ever, and he quotes one official as stating "If only they could invent a weapon which would destroy the entire occupying force without harming a single German they would be only too happy."

Dr. Murray speaks glowingly of science in the Russian Zone, in particular of the 'Chamber of Technology' which he describes as a horizontal grouping of scientists organised in the Free German Trades Union Federation with activities equivalent to a synthesis of the so-called 'Science Policy' work of the British A.Sc.W. and the functions of the professional institutes (which have not been allowed to re-form in the Russian Zone). Dr. Murray sees great hope for German science if it organises on A.Sc.W. lines, and he advocates that the A.Sc.W. should build strong links with German scientists at national level and also by stimulating correspondence between organised groups in this country and Germany, for example the I.C.I. branch at Blackley and the scientists at I.G. Leverkusen.

At the end of the article there is a hint that the A.Sc.W. may approach the British Foreign Office about these matters.

Scientists Collaborate with Politicians

SIR JOHN ANDERSON has been re-elected President of the Parliamentary and Scientific Committee. Vice-presidents of this organisation are LORD BRABAZON OF TARA, LORD CHERWELL, PROFESSOR E. N. DA C. ANDRADE, DR. W. R. WOOLDRIDGE, LORD MARLEY, RT. HON. CLEMENT DAVIES, PROFESSOR ALEXANDER FINDLAY, and SIR IAN HEILBRON. Vice-chairman is SIR CHARLES GOODEVE; MR. RAYMOND BLACKBURN and MR. F. J. ERROLL, both M.P.s, are the deputy-chairmen, and MR. F. A. COBB, M.P., is joint hon. secretary. Hon. treasurer is MR. F. A. GREENE of the Institution of Chemical Engineers.

In America a body similar to our Parliamentary and Scientific Committee has been established, this step being directly inspired by the article "Scientist and Politician as Partners" contributed by MR. HUGH LINSTEAD to *Science* (July 16, 1948). A corresponding body was formed in Canada in April 1947.

The Bookshelf

Human Knowledge: its Scope and Limits. By Bertrand Russell. (Allen & Unwin, London, 1948; pp. 538, 18*s*.)

BERTRAND RUSSELL's latest book is of the utmost importance to science and scientists. Its theme is a discussion of the relationship between individual experience and what we term 'scientific knowledge'. It seeks to assess the objectivity of human knowledge and more especially that part of it which we know through the formulations of science. As the author says "it is a commonplace to say that the substantial inferences of science, as opposed to those of logic and mathematics, are only *probable*—that is to say, when the premises are true and the inference is correct the conclusion is only *likely* to be true. It is therefore necessary to examine what is meant by probability." This Russell does at some length, expending over eighty pages (divided into seven chapters) on the consideration of this particular problem. This is the most difficult part of the book for the ordinary reader who will find the parts dealing with the 'Mises–Reichenbach Theory' and 'Probability and Induction' particularly hard to follow. If, however, the unmathematical can rid themselves of the psychological fear of symbols they will find the arguments surprisingly clear and easy to understand, despite the great complexity of the subject matter. Clarity of exposition and thought is in fact the great feature of this book. A biologist may not agree with Russell's theory of perception —the reviewer in fact *does* find himself in agreement—while a philosopher may quarrel with much of the latter part of the book, but both at least will gain a clear view of what Russell accepts and proposes, which in turn will help to clarify or nullify their disagreements.

This book contains no startlingly new revelation of outlook, no new gospel or synthesis, yet it will take its place in the history of philosophy as one of the greatest expositions of scientific empiricism. There can be no question that this book establishes that Russell is still one of the greatest living philosophers, and it is to be hoped that justified though he would be in so doing, he will not yet lay down his pen and enjoy the honourable retirement from active work which he so well deserves.

DEREK WRAGGE MORLEY.

The Heavens Above. A Rationale of Astronomy. By J. B. Sidgwick. (Oxford University Press, London, 1948, pp. 282, 21*s*.)

MR. SIDGWICK's subtitle made me apprehensive; a science which can be thoroughly codified has usually finished progressing, and astronomy certainly has not yet reached that stage. But I was in for a pleasant surprise: what Mr. Sidgwick aims to do is to explain how such astronomical statements as "The distance of that star is 10 light years" are founded. He has a very pretty style, and an even prettier consciousness that all astronomical measurements are subject to error. So, in reading the first half of the book which deals mainly with geometry—the distances and spatial distribution of astronomical objects—one is continually noting pleasant little features of novelty in his manner of putting things. One raises one's eyebrows a little over a rather misleading statement dealing with the satellites of Uranus, and again over his treatment of the so-called 'Local Cluster' of stars near the sun, but these are literally the only points in this half of the book at which one could cavil, and it is hard to remember a better exposition of this part of the subject. Mr. Sidgwick is particularly good on history, and his book will be of great value for everyone who wants to know who did what and when. Mr. Sidgwick scores so heavily in the first half of his book because his method is ideally adapted to the exposition of any topic in which there is a simple logical train of thought leading to a final fully developed system of ideas.

The second half of his book deals with astrophysics and, unfortunately, his method is here more of a hindrance than a help. Astrophysics, dealing as it does with all physical aspects of stellar material has a fair claim to be regarded as the most comprehensive of all sciences, and anyone who sticks to a single logical thread either in exposition (or in research) is probably in for trouble. So we find Mr. Sidgwick being forced into seeing final systematisation where it may not exist. For him the sequence of nebular types must be evolutionary, and he regards this statement as certain whereas he puts a discussion of stellar energy generation by nuclear reactions under the heading of speculation. His dilemma is most acute in the case of the sun: what we know about the sun consists of a vast mass of observations which cannot yet be subsumed into a system.

When all is said and done, this is a most worthwhile book which makes excellent reading. If, as there should be, there is a second edition, Part I should be left pretty well as it stands, but Part II should be recast.

D. S. EVANS.

Electrons, Atoms, Metals and Alloys. By Dr. William Hume-Rothery, F.R.S. (The Louis Cassier Co., London, 1948; pp. 377, 165 illustrations, 25*s*.).

"THE work of the last thirty years has led to great advances in the theory of the structure and properties of metals and alloys." By no means a minor contribution to the fundamental work in this field was made by the long series of researches carried out on the structure of light alloys by Dr. Hume-Rothery during the war. It happens that for a while I saw, during my then Civil Service duties, some thousands of research reports covering many years of research into this metallurgical field. Towards the end of the war it was obvious that the basic principles in metallurgy were no longer to be assessed by empirical methods, and for one whose metallurgical training was that of the 'old school', I was hoping that someone would prepare a comprehensive textbook relating the fundamental particles and properties of matter with the properties of alloys for my guidance. Dr. Hume-Rothery has written that book.

He first wrote *Atomic Theory for Students of Metallurgy* for university honours students; but it was not a book to be readily understood by those already in the industry. He then considered "why the average physical text-book often proves unattractive to readers outside universities." He concluded: ". . . the usual text-book not only requires a considerable power of continuous concentration, but also expects the reader of any one chapter to retain clearly in his mind the lessons learnt in earlier chapters."

Dr. Hume-Rothery has overcome these difficulties by arranging his text in this book in the form of a Platonic dialogue between the "Older Metallurgist" and the "Younger Scientist". In this way the author has cleverly managed to raise at the appropriate time in the text the very questions, which arise in the reader's mind. He has avoided anything of the tedious question and answer type, with the result that continuity is maintained. The author's style is as crisp as is possible in scientific work, and he is not afraid to use, clearly, mathematics where essential. He includes excellent suggestions for further, detailed study.

Another advantage of his dialogues is that it allows the author to raise pertinently and wittily several important topics and observations, which would be difficult to introduce into a straightforward narrative.

It is hoped that this book, well-indexed, will be widely read and thus impress upon many that many modern metallurgical problems rest upon a full understanding of the behaviour of the electron and atom for their solution.

I. B. N. E.

Synthetic Resin Chemistry for Students. By S. R. W. Martin. (Chapman & Hall, London, 1948, pp. 150, 15*s*.)

THIS book is intended primarily as a text book for those attending classes in Resin, Paint or Plastics Technology, and for junior workers in laboratory or factory handling plastics and synthetic resins. As its title implies, it is concerned mainly with production of synthetic resins and does not cover in any detail their practical applications in industry. The emphasis throughout is on resins used in the paint, varnish and allied trades. A knowledge of School Certificate chemistry is assumed, and each chapter consists of a theoretical development, followed by a practical section with details of experiments actually carried out. The matter is clearly and concisely presented and the experimental examples are especially to be commended for students.

Errors in the text are few and are mostly confined to one page (page 45), but the index, for a text-book, is somewhat sketchy.

It is perhaps both a criticism and commendation of this book to say that it gives one a tantalising half-glimpse of the mysteries of synthetic resin technology and awakens the desire for further, more detailed information.

D. LEE.

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